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THE

PRACTICAL STEAM ENGINEER'S GUIDE

IN THE

Design, Construction and Management

OF

AMERICAN STATIONARY, PORTABLE AND STEAM FIRE-ENGINES, STEAM PUMPS, BOILERS, INJECTORS, GOVERNORS, INDICATORS, PISTONS AND RINGS, SAFETY VALVES, AND STEAM GAUGES.

For the Use of Engineers, Firemen and Steam Users.

BY

EMORY EDWARDS,

AUTHOR OF "A CATECHISM OF THE MARINE STEAM ENGINE," "MODERN AMERICAN MARINE ENGINES, BOILERS AND SCREW PROPELLORS."

Illustrated by One Hundred and Nineteen Engravings.

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Dedicated

TO

MY BROTHER.

FREDERICK W. EDWARDS,

ENGINEER.

PREFACE.

In presenting this book to the engineers, firemen, and steam-users of this country, the writer indulges the hope that it will be found a valuable guide and assistant in their daily labors. To the engineers and firemen it will prove a book of ready reference; and it will also enable those who own or use steam power to exercise an intelligent supervision over their steam machinery, and those whom they employ to manage it. The writer's principal object in getting up this book is to give such information as seems best calculated to raise the *status* of the engineers (the men who *run* steam engines), and to try to induce them to pursue their inquiries in other works on the subject, written by abler pens.

It is a well-known fact that the great majority of those who *run* steam engines are men of rather limited education — the three R's representing about their sum-total in that respect—and hence a book to be of any *practical* value to them must of necessity be written in language which they can understand, and not in symbols beyond their comprehension.

There are men who have had charge of steam engines and boilers for years and years, who run them every day and all day long, who but dimly understand the principles either of the construction or operation of the mighty machines over which they assume charge. Some few of them, with a laudable desire to improve themselves in this respect, fly to books on the subject for aid, but are met on the very threshold by pages upon pages of algebraical formulæ; "Thermal Equivalents;" "Laws of Thermodynamics;" "Isothermal and Adiabatic" curves; $x+y$, etc., (very useful things to those who can understand and apply them, but) which to these men are as meaningless and useless as so much Greek or Latin. Disappointed and disgusted, they put the book carefully away—never to make any further effort to go on in their pursuit of knowledge. Now this book is intended for this very class of men (as a stepping-stone for something higher and better)—men who have much to learn—and not for "experts" who have nothing to learn; and therefore those who may be disposed to criticise will do well to bear this fact in mind.

The want of a proper education on the part of these men is something to be deplored; but it must be remembered in their behalf that many of

them were when boys driven by poverty to go out into the world and battle for bread, when they should have been, by right, at school, getting that greatest of all blessings—a good education. Knowing this, the writer has used the plainest and simplest language, so that it can be easily understood by those for whom it is intended—the worthy seekers after "more light." To those "runners" who scout all book-learning—the "rule of thumb" men who imagine in their ignorance that what *they* (!) don't know about steam and steam engines is not worth knowing, the writer has nothing to say, but will only add that "there is more hope for fools than *such* men."

After a brief review of the history of the non-condensing steam-engine, will be found in this volume many of the most popular makes of steam-engines, by our most celebrated builders, fully described and illustrated. The one particular object for so doing is this: stationary engineers, as a rule, seldom remain for any length of time at one place, and are ever, for one reason or another, changing from one situation to another. In nearly every case they are brought in contact with a different make of engine from the one to which they were accustomed, and it frequently takes them days, if not

weeks, before they get "the hang of the thing," as they express it. The essential difference between the different makes of engines is in the valves and valve-gear; in other respects there is very little difference, if any. In this chapter the writer has illustrated and fully described the valves and valve-gears of each particular engine; so that no matter which one the engineer may be called upon to take charge of, he can do so intelligently, to the credit of himself and satisfaction of his employers.

An engineer needs to read, study, and advance himself in his business. The trade is a progressive one; new facts are daily being discovered in the employment of steam and adaptation of steam machinery and appliances. He who professes to be a steam-engineer, and does not make an effort to keep informed as to the new developments in his profession, will find his usefulness growing beautifully less and his services valued accordingly.

On the other hand, the unskilled coal-shoveler, who applies himself to study and research to acquire a practical knowledge of steam-engineering, will generally qualify himself for a steady position at good wages.

Employers are often much to blame for engaging

a cheap, incompetent class of men to run their engines and boilers, without regard to their fitness. They are too much inclined to regard wages as of the greatest consequence in deciding whom to employ.

It is almost useless for engineers to try to educate the whole class of steam-users as to the danger and pecuniary loss involved by employing ignorant, unskilled men to manage their boilers and engines. Some progress may be made with the earnest co-operation of the engineers' press, *but the task will never be fully accomplished.*

All that can be done, therefore, is to place within the reach of mill-owners, superintendents, and other "bosses" (as well as engineers and firemen), the means by which they can intelligently supervise the steam as well as other departments under their charge.

The writer has often been requested by young and intelligent engineers and mechanics to name such newspapers and books devoted to steam engineering as would prove beneficial to them in their pursuit of knowledge, and aid them to keep themselves posted in this age of rapid progress. To such he would say, read and study *all* the papers and books on the subject you can put your

hands on; but possess by all means, for a *history* of the steam engine from the time of Hero, 200 B. C., down to 1881, "The Growth of the Steam Engine," by Prof. R. H. Thurston; and for the *theory* of the steam engine—"A Text-book on the Steam Engine," by T. M. Goodeve. Both of these valuable books can be had of the publishers of this work. As regards engineers' newspapers, the "*American Machinist*" and the "*Mechanical Engineer*" are two that no engineer, young or old, can afford to be without.

In conclusion, the writer begs to say that he does not claim *entire* originality for this work—*original* books on the subject are hard to find—indeed, the subject of the steam engine is one that has been so written up and written down by numerous writers of late years, that there remains little or nothing original to be said about it. All that any one in the present or future can do in preparing books of this kind is to go over the beaten track; cull over that which has gone before; select the wheat from the chaff, and present that which is really useful and practical stripped of all engineering rubbish which is worthless and obsolete, and which only adds to the size and cost of a book without increasing its value.

To each and all of those kind friends who aided him in any manner in the preparation of these pages, he returns his best thanks.

THE AUTHOR.

512 *Washington St., Wilmington, Del.,*
May 24, 1882.

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INTRODUCTION.

QUALIFICATIONS FOR ENGINEERS, AND PHILOSOPHY OF THE STEAM-ENGINE.

Ques. What qualifications are necessary for an engineer?

Ans. The very first qualification is *sobriety.* No man who drinks intoxicating liquors to excess is fit to be an engineer, fireman, or in fact anything else about a steam-engine; and the law should be so amended as to prohibit, under the severest penalties, the employment of such men. A drunken engineer or fireman may not only destroy himself, but hundreds of innocent men, women, and children.

Ques. Should not an engineer be a machinist by trade?

Ans. Not necessarily so, but he should be a man of "mechanical ideas." Practical steam-engineering consists in the *tact* of the engineer in discovering faults in the working of his engine, and in applying the proper remedy. An engineer must be something of a machinist, boiler-maker, copper-smith, and steam-fitter. A man might be a good machinist but a poor engineer, from want of *tact.*

Ques. What course should a man pursue to become a good practical engineer?

Ans. Go into the fire-room as a fireman, and by attention to duty, industry, and by general good conduct, work his way up. He must keep his eyes and his ears open, and learn something every day; when machinists, boiler-makers, copper-smiths, or steam-fitters come about to make repairs, watch them and see how they make them, and thereby learn how to make them himself. He should visit all the machine-shops he can, and also other places, so as to become familiar with the mode of construction and different types of engines and boilers. He should not be either ashamed or afraid to ask for information about anything he does not *thoroughly* understand. He should not play the "smart-Alec," pretending to know a great deal more than he really does, for "there is more hope for a fool than such a man." True merit is always modest. And last but not least, he should keep himself read up in his business. Steam-engineering is progressive, and he must keep himself posted on the improvements of the day by reading all books and papers relating to the profession, and not trust to his own experience, which is necessarily limited, alone.

PHILOSOPHY AND OPERATION OF THE STEAM-ENGINE.

Ques. Will you explain to me the philosophy and operation of the steam-engine, so that I may under-

stand the principles as well as the practice of the same?

Ans. In the operation of the steam-engine we find illustrated many of the most important principles and facts which constitute the physical sciences.

The steam-engine is an ingenious, but still a very imperfect machine for transforming the heat-energy obtained by the chemical combination of a combustible (anything that will burn) with the supporter of combustion (the oxygen of the air) into mechanical energy or power. But the original source of all this energy is found far back of its first appearance in the steam-boiler; it began when all nature came into existence. After the solar system had been formed from the nebulous chaos of creation, the glowing mass, which we now call the sun, was the depository of a vast store of heat energy, which was thence radiated into space and showered upon the attendant worlds in unmeasured quantity and intensity. The heat thus received from the sun upon the earth's surface was partly expended in the production of great forests, compared with which our present forests are as a barren waste; and in those trees was stored an immense quantity of carbon, which had previously existed in the atmosphere, combined with oxygen as carbonic acid. The great geological changes which buried these forests under superincumbent strata of rock and earth, resulted in the formation of *coal-beds*, and the storage during many succeeding ages of a

vast amount of carbon, of which the affinity for oxygen remained unsatisfied until finally uncovered by the hand of man.

Thus, you see, we owe to the heat and light of the *sun*, as was pointed out by the immortal Stephenson years ago, the incalculable store of energy upon which the whole human race is so entirely dependent, not only for the comforts of life, but for life itself.

This coal thrown upon a grate in a steam-boiler, takes fire, and, uniting again with the oxygen, sets free heat in precisely the same quantity that it was received from the sun and appropriated during the growth of the tree—no more, no less. This heat is transmitted by conduction and radiation to the water in the boiler, converts it into steam, and its mechanical effect is seen in the expansion of the liquid into vapor against the superincumbent pressure. Transferred from the boiler to the engine, it is there permitted to expand, doing work, and the heat-energy with which it is charged becomes partly converted into mechanical energy.

Thus we trace the store of energy received from the sun and contained in our coal through its several changes, until it is finally set at work, and we might go still further and observe how, in each case, it is again usually retransformed and again set free as heat-energy. The transformation which takes place in the furnace is a *chemical* change; the transfer of heat to the water, and the subsequent

phenomena accompanying its passage through the engine, are *physical changes*, some of which require for their investigation abstruse mathematical operations; it also involves the study of chemistry and physics, and especially of the science of thermodynamics, which is peculiarly the science of the steam-engine, and other heat engines.

But again, to explain more fully the operation of the steam. The steam with its store of heat-energy passes through tortuous pipes and passages to the steam-cylinder of the engine, losing more or less heat on the way, and there expands, driving the piston before it, and losing heat by the transformation of that form of energy while doing work of equivalent amount. But this steam-cylinder (as well as the boiler) is made of iron, a material which is one of the best conductors of heat, and therefore one of the very worst substances with which to enclose anything as subtle and difficult of control as the heat pervading a condensable vapor like steam.

The process of internal condensation and re-evaporation, which is the greatest obstacle to economical working, thus has full play, and is only checked by the heat from the steam-jacket, which, penetrating the cylinder, assists by keeping up the temperature of the internal surface and checking the first step, condensation, which is an essential preliminary to the final waste by re-evaporation. The piston being also made of iron or other metal, affords a most excellent way of exit for the heat

escaping through it to the exhaust side. That you may thoroughly understand the operation of the steam-engine, see Figure 1 of a condensing steam-engine in actual work, which will make it all plain and easily understood. The principles governing the operation of the steam-engine are the same, whatever the design or construction, and therefore this explanation of the operation of a steam-engine, together with what has been said, will suffice for any and every type, as they only differ in detail or arrangement of the various parts. There is in every case one or more boilers in which the steam is generated; one or more steam-cylinders, in which the steam is utilized; a condenser, in which the steam is condensed—turned into water again—which in turn produces a vacuum in the condenser and in the exhaust side of the cylinder; an air-pump for removing the water from the condenser as fast as it runs in, and also the air which enters with it, as well as any steam vapor remaining uncondensed; a hot well from which hot water is taken for the boilers, and one or more feed pumps for supplying the same. All of the other (working) parts are simply mechanism, connecting the power with the resistance, working the valves, etc., the function of each of which will be found explained elsewhere in this book. AA, A, A, is the frame, or gallows frame, as it is usually designated; B, the beam; C, the connecting-rod; D, the crank; E, the shaft; F, links; G, piston-rod; H, piston; K,

cylinder; L, condenser; M, side-pipes; N, valves; O, air-pump; P, hot well; R, air-pump piston; S,

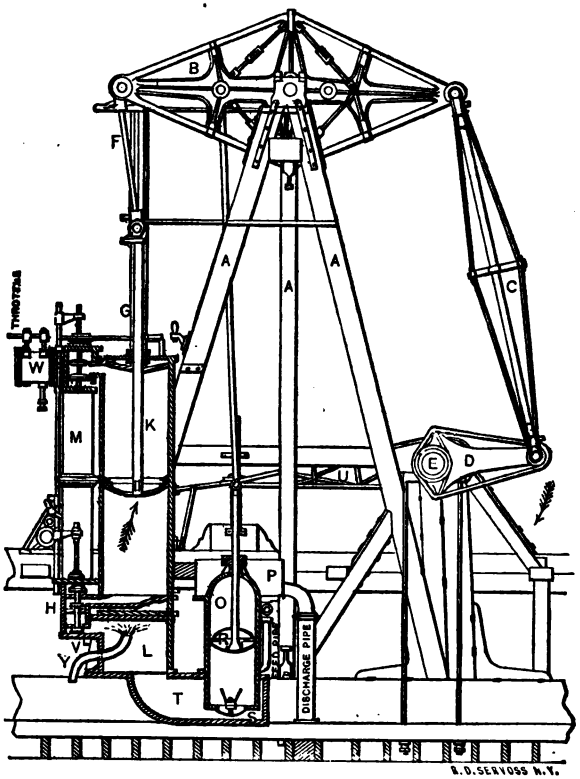


Fig. 1.

foot valve; T, channel way; U, eccentric rod; W, steam-pipe; Y, injection pipe.

Now, supposing this engine in motion, the steam

is entering the cylinder through the lower steam-valve and driving the piston up, as shown by the arrow; at the same time the upper exhaust valve is open, allowing the steam which had previously driven the piston down, to escape to the condenser, leaving a vacuum in the cylinder on that, the exhaust side of *that* stroke. During this up stroke the upper steam and lower exhaust valves are closed. (On the down stroke the movement of the valves will be reversed.) The exhaust steam rushes through the exhaust side-pipe into the condenser, where it is instantly condensed by a shower of cold water entering through the injection pipe. As fast as the condensing water flows in, it passes through the foot-valve to the air-pump, and as the air-pump piston ascends, fills the barrel of the air-pump. When the air-pump piston descends, the foot-valve closes, which prevents the water returning to the condenser; the valves in the air-pump piston open, the water passes through to the upper side, together with the air and uncondensed vapor mixed with it; from thence to the hot-well, and all not required for feeding the boilers goes waste through the discharge pipe, and this is repeated over and over again so long as the engine is in motion.* In this case the condenser is of the "jet" type, in which the water flows in, forced by the atmospheric pressure; in the surface condenser

* In a non-condensing engine there would be no condenser or air-pump, and the steam would exhaust into the atmosphere.

the water is driven through the tubes by an independent pump. The difference between these two types of condenser will be found more fully explained elsewhere.

Ques. Explain in simple language the gain by expanding steam?

Ans. It saves steam, but it diminishes the power of the engine while increasing the efficiency of the steam. For instance, if the steam be cut off at half-stroke there will only be half the quantity of steam used, but there will be more than half the power exerted, because the steam in expanding does *some* work, and that is a clear gain.

Ques. What will be the pressure at the end of the stroke?

Ans. If cut off at half-stroke it will be one-half the initial pressure, whatever that may be; if at one-third the stroke it will be one-third; if at one-fourth it will be one-fourth, and so on. According to the well-known law of pneumatics, the pressure of elastic fluids varies as the space into which they are expanded or compressed. Thus if a cubic foot of steam, at ten pounds pressure, be compressed into one-half a cubic foot, the pressure will be twenty pounds; but if expanded into two cubic feet it will be only five pounds, provided the *temperature* remains unaltered. In estimating the pressure in a *condensing* engine, the atmospheric pressure must be included. Thus, if the steam-gauge shows 20 pounds, and the vacuum gauge

shows 28 *inches* (2 inches equal one pound pressure), the initial pressure will be 20+14=34 pounds per square inch.

Ques. Then I understand that by working the steam expansively, the power of the steam is increased, but the power of the engine diminished?

Ans. That is the idea exactly. It will require a larger engine to do the work, but it will do it with a less amount of steam.

Ques. Will you give me a rule by which I can find at one operation the amount of gain derived from expansion?

Ans. Divide the distance through which the steam expands by the distance the piston travels before the steam is cut off (which last call I); the hyperbolic logarithm of the quotient is the increase due to expansion. According to this rule it will be seen, that if a given quantity of steam (the power of which working at full pressure is represented as I) when cut off a half stroke (*i. e.*, expanded twice) the efficiency is raised by expansion 1.69+ ; at one-fourth stroke to 2.39+. See table of hyperbolic logarithms in the Appendix.

Ques. Is this amount of gain realized in practice?

Ans. Well, hardly ever. The above is the gain by theory alone; but in actual practice, unless the cylinder is provided with a steam-jacket to keep it hot, or well felted and lagged, there is little or no gain. In some cases it has been found by experiment that less benefit was obtained by using the cut-off than when following full stroke.

Ques. Will you explain this matter by means of a diagram, so that I may thoroughly understand it?

Ans. Let the diameter of the cylinder in the following figure be, say 10 inches for the sake of simplicity, and length of stroke 20 inches. Pressure equal 10 pounds. We will divide the diameter into 10 equal parts, and the stroke into 20 equal parts. Steam enters the cylinder, and follows at full pressure (which call I) until the piston reaches C, C, when the valve closes and cuts off the steam. The steam, shut up in the cylinder, then expands, and drives with a constantly diminishing pressure to the end of the stroke E, E. Now, looking at the figure, you will see that at half stroke (10 inches) the pressure has fallen to .500,

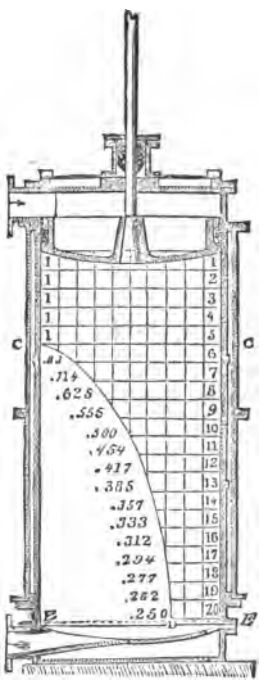


Fig. 2.

or one-half (5 pounds), and at the end of the stroke to .250, or one-quarter ($2\frac{1}{2}$ pounds). The sketch shows the pressure at intermediate points. Now, if these series be set off on horizontal lines, they will mark out a *hyperbolic* curve (the curved line C D),

and the squares below C C show the gain by expansion, while the blank space shows the loss of power. If you count the squares above C C, before the steam was cut off, they will be found to number 50, while those below C C, after the steam-valves closed, you will find 69+. These squares represent the power exerted by the steam before and after expansion, and you will notice that while it took a quarter of a cylinder full of steam to get 50 of them, we get 69+ without expending any steam at all, by merely permitting the steam to expand into four times its original volume. As before stated, this is the *theoretical* gain, and only approximately true when applied to steam-engines in actual use, but which should, nevertheless, be understood by practical engineers, and all others who desire to get above the "rule of thumb."

Ques. What is meant by the centre of gravity of a body?

Ans. It is that point within it, in which the whole *weight* may be supposed to be concentrated. A body hung in its centre of gravity, will remain at rest in any position.

Ques. What is meant by the centre of gyration?

Ans. It is that point in a *revolving* body in which the whole *momentum* may be conceived to be concentrated.

Ques. What is meant by the centre of oscillation?

Ans. It is the point in a pendulum or other *swinging* body, that if all the matter of the body were

collected into that point, the velocity of its vibration would remain unchanged.

Ques. What are the mechanical powers?

Ans. The five elementary machines known as the lever, wheel and axle, inclined plane, wedge, and screw, which convert a small force acting through a great space into a great force acting through a small space.

Ques. What is meant by mechanical power?

Ans. Any pressure acting through a certain space with a certain velocity can be converted into a greater pressure, with a less velocity, through a smaller space, and the quantity of mechanical force or power remains unchanged; and all that the above so-called mechanical powers are used for is to effect this transformation. They do not and cannot create power or force, because *that* is eternal, and can neither be created nor destroyed. It requires just the same amount of force to lift one pound through 100 feet as it does to lift 100 pounds through one foot in the same time.

Ques. What is meant by friction?

Ans. It is the resistance experienced when one body is rubbed upon another body, and is supposed to be caused by the interlocking of the unseen prominences which exist upon all bodies, however smooth they may seem to the eye or touch. Mr. Joule found by experiment that so much power is expended in heating one pound of water one degree by friction as would raise a pound weight 772 feet high, and this measure of power is consequently termed the "mechanical equivalent" of heat.

Ques. Does friction increase with the extent of the rubbing surfaces?

Ans. It does not, so long as there is no heating or cutting; it is simply in proportion to the pressure keeping the bodies together; from which it will be seen that it is advantageous to have the bearings of steam-engines as large as possible, as increased surface does not increase the friction, while there is a great increase in durability. When the bearings are too small, they are apt to heat and soon wear out.

Ques. What amount of power is necessary to overcome friction?

Ans. That depends on the rubbing surfaces. Iron rubbing on iron is estimated at $\frac{1}{10}$ of the pressure: and iron on brass at $\frac{1}{11}$ on surfaces not lubricated; but when well lubricated with good lard oil, or oil and plumbago (like Dixon's), it can be reduced to $\frac{1}{33}$ or even less. The friction of smooth rubbing substances is always less when the composition of those substances is different—like iron on brass.

Ques. What is meant by latent heat?

Ans. It is the heat existing in bodies which is not discoverable by the touch or thermometer, but which manifests itself by producing a change of state.

Ques. What is meant by the latent heat of steam?

Ans. The heat contained in vapor above that necessary for producing the temperature. It requires as much heat to raise one pound of boiling water (at 212°) into steam as is required to raise $5\frac{1}{2}$ pounds of water from the freezing point (32°) to the boiling

point (212°). In steam at 212° there are 212° of sensible heat, and about 1000° of latent heat—the sum of sensible and latent heats being *about* 1212° for all pressures, for as one increases the other decreases.

Ques. What is meant by specific heat?

Ans. The relative quantities of heat in bodies at the same temperature, just as by specific gravity is meant the relative quantities of matter in bodies of the same bulk. Equal weights of quicksilver and water at the same temperature do not contain the same quantities of heat, any more than equal bulks of them contain the same quantities of matter.

CHAPTER I.

STANDARD AMERICAN STATIONARY ENGINES.

THE high-pressure or non-condensing engine was invented and first introduced by Oliver Evans, an American. This truly great man—of whose name and fame every American should be proud—was one of the most ingenious mechanics that this country has ever produced. He was born in the little village of Newport, Delaware, in 1755 or 1756, of parents in humble circumstances. He was, when a boy, apprenticed to a wheelwright, during which time he exhibited wonderful mechanical talent, and a strong desire to obtain knowledge. Subsequently meeting with a description of Newcomen's atmospheric engine, he at once noticed that the elastic force of the confined steam was not there utilized. He then designed the *non-condensing* engine, in which the power was derived exclusively from the tension of high-pressure steam.

In 1786 he applied to the Pennsylvania Legislature for a patent for the application of the steam-engine to driving mills, but was refused it. About the year 1800 he commenced the construction of a steam carriage to be driven by a non-condensing

engine; but afterwards concluded that it would be better, pecuniarily, to adapt his engine, which was novel in form, and of small first cost, to driving mills. He accordingly changed his plans, and built an engine six inches diameter of cylinder, and eighteen inches stroke of piston, which he applied with perfect success in driving a plaster mill. This engine, which he called the "Columbian Engine," was of a peculiar form, as shown in Fig. 3.

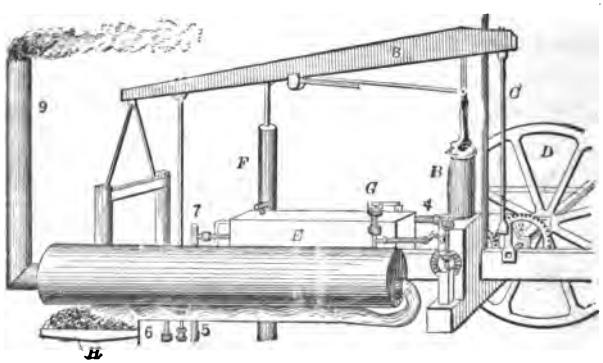


Fig. 3.—Evans' Non-Condensing Engine, 1800.

The beam was supported at one end by a rocking column, and at the other it was attached directly to the piston-rod, while the crank was situated beneath the beam. The connecting-rod was attached to the extreme end of the beam. The head of the piston-rod was compelled to rise and fall in a vertical line, by the "Evans parallelogram"—a kind of parallel motion very similar to that designed by Watt. In Fig. 3, A is the boiler; B, the cylinder; C, the con-

necting-rod; D, the fly-wheel; E, steam-drum; F, feed-pump; G, safety-valve; H, grate bars; 2 and 3, geared valve motion; 4, steam-pipe; 5, 6 and 7, feed-pipe; 8, the beam; 9, smoke-pipe. The flames from the furnace pass under the boiler, between brick walls, and back through the central flue to the chimney. Subsequently, Evans continued to extend the application of his engine, and perfect it in detail. He continued to build engines until he died—which sad event took place April 19, 1819—applying them with success to steamboats on the western rivers, to flour mills, saw-mills, dredging machines, elevators; in fact, wherever steam power could be applied. He has deservedly been called, "The Watt of America."

After Evans had passed away, other builders in different parts of the country went into the business, and steam-engine building became one of the great industries of the land. These engines were at first rude in design, badly proportioned, rough and inaccurate as to workmanship, and uneconomical in the consumption of fuel. Gradually, however, they assumed neater and stronger shapes, good proportions, were well made, and of good material, until to-day the American stationary engine is equal, if not superior, to any made in Europe or elsewhere. To prove this the reader has but to examine the many splendid examples by our best makers, to be found in this book. In stationary engines the United States leads the world.

Fig. 4 shows the style of engine which was the

standard type in the United States for many years, and which is still in use in many sections of the country. It is still the standard in locomotive practice, but for stationary purposes it is fast giving way to the Corliss, Wheelock, and other first-class engines. We will now proceed to describe and illustrate the engines designed and constructed by many of our

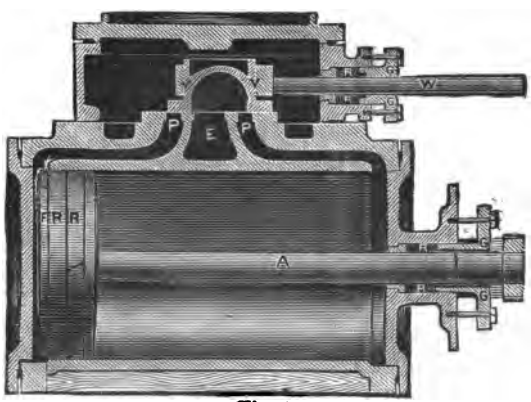


Fig. 4.

VV—Valve; W—Valve-stem; PP—Steam-ports; E—Exhaust-ports; K—Stuffing-boxes filled with packing; A—Piston-rod; RR—Piston-rings; F—Follower; G—Glands.

most celebrated builders, with the object of making the engineer familiar with their design, construction, and operation, so that no matter which one or kind he may be called upon to take charge of, he will find no difficulty in running it successfully, to the credit of himself and the satisfaction of his employers.

One of the neatest and best modern designs of

stationary engines for small powers is seen in Fig. 5, which represents a "vertical direct-acting engine,"

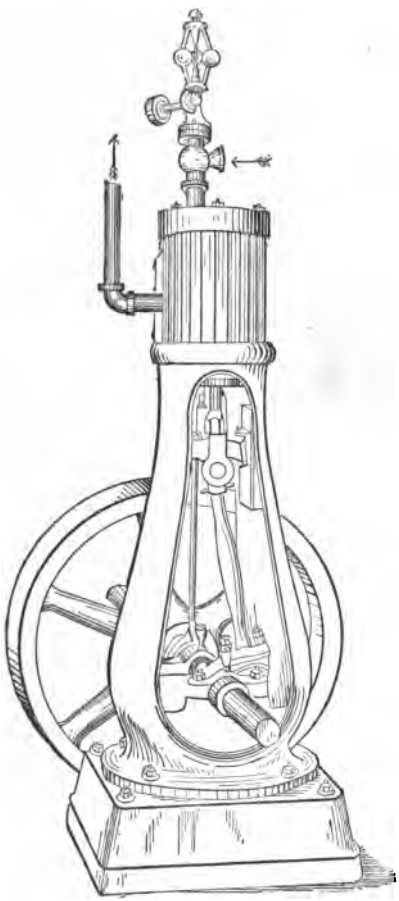


Fig. 5.

with base-plate, a form which is a favorite with many engineers.

This type of engine consists of two principal parts, the cylinder and the frame, which is a tapering column having openings in the sides, to allow free access to all the working parts within. The slides and pillow-blocks are cast with the column, so that they cannot become loose or out of line; the rubbing surfaces are large and easily lubricated. Owing to the vertical position, there is no tendency to side-wear of cylinder or piston. The packing-rings are self-adjusting, and work free but tight. The crank is counter-balanced; the crank-pin, crosshead-pin, piston-rod, valve-stem, etc., are made of steel; all the bearing surfaces are made extra large, and are accurately fitted; and the best quality of babbitt-metal only used for the journal-bearings. The smaller sizes of these engines, from 2 to 10-horse-power, have both pillow-blocks cast in the frame, giving a bearing each side of the double cranks. They are built by some constructors in quantities, and parts duplicated by special machinery (as in fire-arms and sewing-machines), which secures great accuracy and uniformity of workmanship, and allows of any part being quickly and cheaply replaced when worn or broken by accident. The next figure (6) is a vertical section through the same engine.

Engines fitted with ordinary rigid bearings require to be erected on firm foundations, and to be kept in perfect line. If, by the settling of the foundation or

from any other cause, they get out of line, heating, cutting, and thumping result. To obviate this, modern engines are often fitted with self-adjusting bearings throughout; this gives the engine great

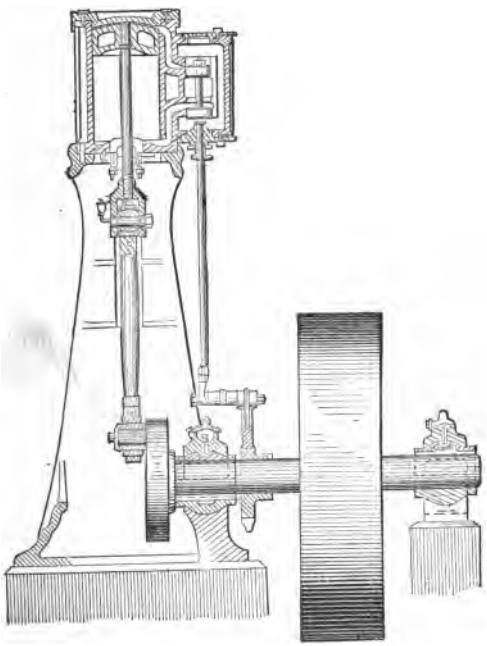


Fig. 6.

flexibility and freedom from friction. The accompanying cut shows clearly how this is accomplished.

The pillow-block has a spherical shell turned and fitted into the spherically-bored pillow-block, thus allowing a slight angular motion in any direction.

The connecting-rod is forged in a single piece, without straps, gibs, or key, and is mortised through at each end for the reception of the brass boxes, which are curved on their backs, and fit the cheek pieces, between which they can turn to adjust themselves to the pins, in the plane of the axis of the rod. The adjustment for wear is made by wedge-blocks and set-screws, as shown; and they are so constructed that the parts cannot get loose and cause a break-down. The cross-head has adjustable gibs on each side, turned to fit the slides, which are cast solidly in the frame, and bored out exactly in the line with the cylinder. This permits it freely to turn on its axis, and, in connection with the adjustable boxes in the connecting-rod, allows a perfect self-adjustment to the line of the crank-pins. The out-board bearing may be moved an inch or more out of position in any direction, without detriment to the running of the engine, all bearings accommodating themselves perfectly to whatever position the shaft may assume.

The ports and valve passages are proportioned as in locomotive practice. The valve-seat is adapted to the ordinary plain slide or D-valve, should it be preferred; but the balanced piston slide valve works with equal ease, whether the steam-pressure is 10 or 100 pounds; and at the same time gives double steam and exhaust openings, which greatly facilitates the entrance of the steam to, and its escape from, the cylinders, thus securing a nearer approach to boiler-pressure, and a less back-pressure, saving the power

required to work an ordinary valve, and reducing the wear of valve-gear. This is a type of engine frequently seen in the United States. The vertical direct-acting engine is sometimes, though rarely, built of very considerable size, and these large engines are more frequently seen in rolling-mills than elsewhere. Where much power is required, the stationary engine is usually a horizontal direct-acting engine, having a more or less effective cut-off valve gear, according to the size of engine and the cost of fuel. A good example of the simpler forms of this kind of engine is the small horizontal slide-valve engine, with independent cut-off valve riding on the back of the main valve—a combination generally known among engineers as the Meyer system of valve-gear. This form of steam-engine is a very effective machine, and does excellent work when properly proportioned to yield the required amount of power. It is well adapted to an expansion of from four to five times. Its disadvantages are, the difficulty which it presents in the attachment of the regulator, to determine the point of cut-off by the heavy work which it throws upon the governor when attached, and the rather inflexible character of the device as an expansive valve-gear.

The best examples of this class of engine have neat, heavy bed-plates, well-designed cylinders and details, smooth-working valve-gear, the expansion-valve adjusted by a right and left-handed screw, and regulation secured by the attachment of the governor

to the throttle-valve. In American engines usually, two supports are placed—the one under the shaft and the other under the cylinder—to take the weight of the engine; and through them it is secured to the foundation. As in the vertical engine already described, a valve is sometimes used, consisting of two pistons connected by a rod, and worked by an ordinary eccentric. By a simple arrangement, these pistons have always the same pressure inside and out, which prevents any leakage or blowing through; and they are said always to work equally as well and free from friction under 150 pounds pressure as under 10 pounds per square inch, and require no adjustment. It is more usual, however, to adopt the three-ported valve—slide-valve such as used on locomotives—with frequently a cut-off valve on the back of this main valve, which cut-off valve is adjusted either by hand or by the governor. Engines of the class just described are especially well fitted, by their simplicity, compactness, and solidity, to work at the high piston speeds which are gradually becoming generally adopted in the effort to obtain increased economy of fuel, by the reduction of the immense losses of heat which occur in the expansion of steam in the metallic cylinders through which we are now compelled to work it. One of the best known of recent engines is the Allen engine, a steam-engine having the same general arrangement of parts as seen in nearly all the horizontal engines, but fitted with a peculiar valve-gear, and having proportions of parts which

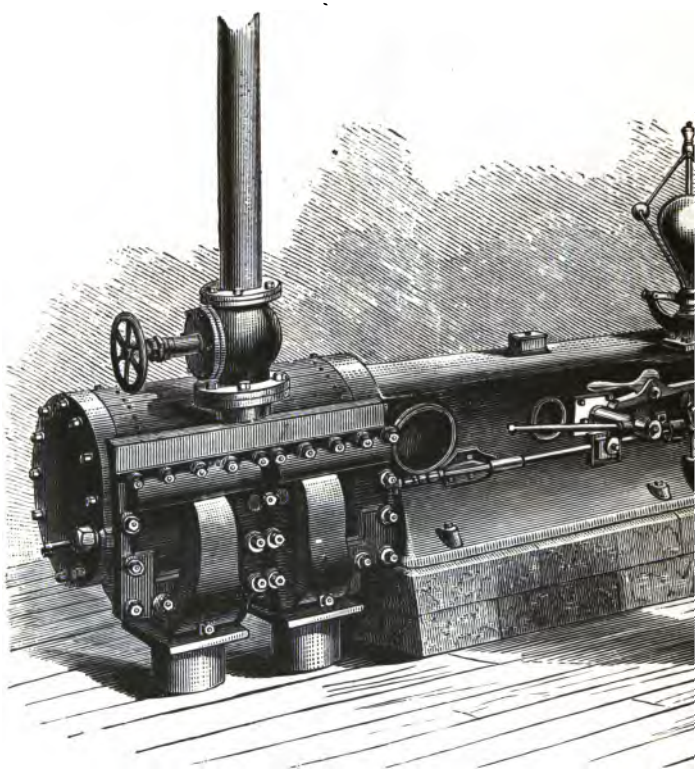
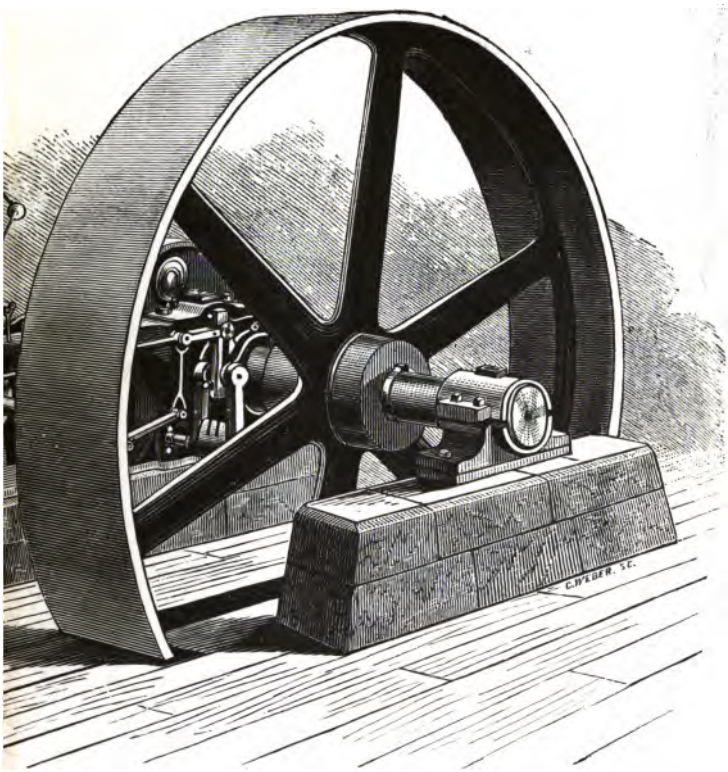


Fig. 7.—THE ALLEN H



-SPEED ENGINE. Page 51.

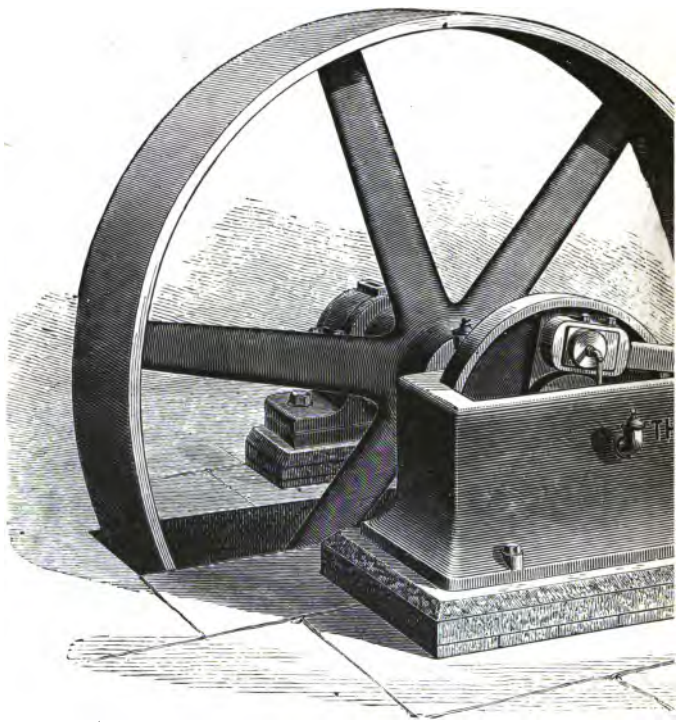
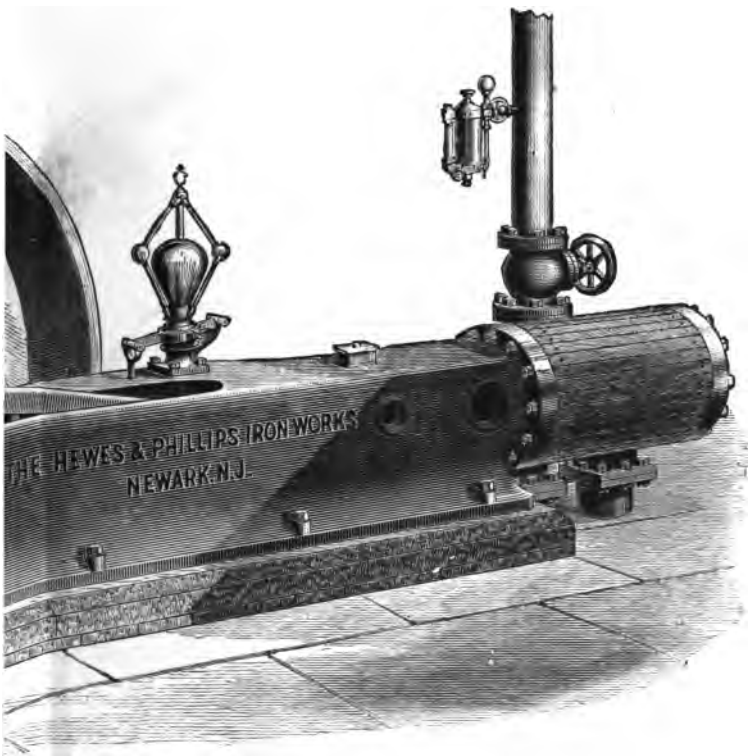


Fig. 8.—ALLEN HIGH-SPEED



ED ENGINE.—FRONT VIEW. Page 51.

are especially calculated to secure smoothness of motion and uniformity of pressure on the crank-pin and journals, at speeds so high that the inertia of the reciprocating parts becomes a seriously-important element in the calculation of the distribution of stresses and their effect on the dynamics of the machine. In the Allen engine, the cylinder and frame are connected as in the engine seen in Figs. 7 and 8. The valve-gear differs in having four valves, one at each end on the steam as well as on the exhaust side, all of which are balanced, and work with very little resistance. The valves are not detachable, but are driven by a link attached to and moved by an eccentric on the main shaft. The position of the valve-rod attachment to the link is determined by the governor, and the degree of expansion is thus adjusted to the work of the engine. The engine has usually a short stroke, not exceeding twice the diameter of the cylinder, and is driven at a very high speed, generally averaging from 600 to 800 feet, piston speed, per minute. This high piston-speed and short stroke give very great velocity of rotation. The effect is, therefore, to produce an exceptional smoothness of motion, while permitting the use of small fly-wheels. Its short stroke enables entire solidity to be attained in a bed of rigid form, making it a very completely self-contained engine, adapted to the heaviest work, and requiring only a small foundation. The journals of the shaft, and all cylindrical wearing surfaces, are finished by grinding

in a manner that leaves them perfectly round. The crank-pin and cross-head pin are hardened before being ground. The joints of the valve-gear consist of pins turning in solid ferrules in the rod-ends, both hardened and ground. After years of constant use thus, no wear occasioning lost time in the valve-movement has been detected. High speed and short stroke are essential elements of economy.

It is now well understood that all the surfaces with which the steam comes in contact condense it. Obviously, one way to diminish this loss is to reduce the extent of surface to which steam is exposed. In engines of high speed and short stroke, the surfaces with which the steam comes in contact, while doing a given amount of work, present less area than in ordinary engines running at slow speed. Where great steadiness of motion is desired, the expense of coupled engines is often incurred. Quick-running engines do not require to be coupled. A single engine may give greater uniformity of motion than is usually obtained with coupled engines at ordinary speeds. The ports and valve-movements, the weight of the reciprocating parts, and the size and weight of the fly-wheels, should be calculated expressly for the speeds chosen. The economy of the engine here described is unexcelled by the best of the more familiar drop cut-off engines.

An engine reported upon by a committee of the American Institute, of which Dr. Barnard was chairman, was non-condensing, 16 inches in diameter

of cylinder, 30 inches stroke, making 125 revolutions per minute, and developed over 125 horse-power with 75 pounds of steam in the boiler, using 25¾ pounds of steam per indicated horse-power, and 2.87 pounds of coal—an extraordinarily good performance for an engine of such small power. The governor used on this engine is known as the Porter governor. It is given great power and delicacy by weighting it down, and thus obtaining a high velocity of rotation, and by suspending the balls from forked arms, which are given each two bearing-pins separated laterally so far as to permit considerable force to be exerted in changing speeds without cramping those bearings sufficiently to seriously impair the sensitiveness of the governor. (Figs. 7 and 8 show one of these engines, as built by "The Hewes & Phillips Iron Works," Newark, N. J.) This engine as a whole may be regarded as a first-class representative of the high-speed engine of to-day.

Since this change in the direction of high speeds has already gone so far that the "drop cut-off" is sometimes inapplicable, in consequence of the fact that the piston would, were such a valve-gear adopted, reach the end of its stroke before the detached valve could reach its seat; and since this progress is only limited by our attainments in mechanical skill and accuracy, it seems probable that the "positive-motion expansion-gear" type of engine will ultimately supersede the now standard "drop cut-off engine." The best known and most generally

used class of stationary engines at the present time is, however, that which has the so-called "drop cut-off," or "detachable valve-gear." The oldest and best known form of valve-motion of this description now in use is that known as the "Sickels cut-off," patented by Frederick E. Sickels, an American mechanic, about the year 1841, and also built by Hogg, of New York, who placed it upon the engine of the steamer South America. The invention is claimed for both Hogg and Sickels. It was introduced by the inventor in a form which especially adapted it to use with the beam engine used on the eastern waters of the United States, and was adapted to stationary engines by Messrs. Thurston, Greene & Co., of Providence, R. I., who made use of it for some years before any other form of "drop cut-off" came into general use. The Sickels cut-off consisted of a set of steam-valves, usually independent of the exhaust-valves, and each raised by a catch, which would be thrown out at the proper moment by a wedge with which it came in contact as it rose with the opening valve. This wedge, or other equivalent device, was so adjusted that the valve should be detached and fall to its seat when the piston reached that point in its movement, after taking steam, at which expansion was to commence. From this point, no steam entering the cylinder, the piston was impelled by the expanding vapor. The valve was usually the double-poppet. Sickels subsequently invented what was called the "beam-motion," to detach

the valve at any point in the stroke. As at first arranged, the valve could only be detached during the earlier half-stroke, since at mid-stroke the direction of motion of the eccentric rod was reversed, and the valve began to descend. By introducing a "wiper" having a motion transverse to that of the valve and its catch, and by giving this wiper a motion coincident with that of the piston; by connecting it with the beam or other part of the engine moving with the piston, he obtained a kinematic combination which permitted the valve to be detached at any point in the stroke, adding a very simple contrivance which enabled the attendant to set the wiper so that it should strike the catch at any time during the forward movement of the "beam-motion."

On stationary engines, the point of cut-off was afterwards determined by the governor, which was made to operate the detaching mechanism, the combination forming what is sometimes called an "automatic cut-off." The attachment of the governor so as to determine the degree of expansion had been proposed before Sickels' time. One of the earliest of these contrivances was that of Zachariah Allen, in 1834, using a cut-off valve independent of the steam-valve. The first to so attach the governor to a drop cut-off valve-motion, was George H. Corliss, who made it a feature of the Corliss valve-gear in 1849. In the year 1855, N. T. Greene introduced a form of expansion-gear, in which he combined the Sickels

beam-motion device with the expansion-adjustment gained by the attachment of the governor, and with the advantage of flat slide-valves at all ports, both steam and exhaust. Many other ingenious forms of expansion valve-gear have been invented, and several have been introduced, which, properly designed and proportioned to well-planned engines, and with good construction and management, should give economical results, little, if at all, inferior to those just named. Among the most ingenious of these later devices is that by Babcock and Wilcox, in which a very small auxiliary steam-cylinder and piston is employed to throw the cut-off valve over its port at the instant at which the steam is to be cut off. A very beautiful form of isochronous governor is used on this design, to regulate the speed of the engine by determining the point of cut-off.

In Wright's engine, the expansion is adjusted by the movement of the regulator cams which operate the steam-valves, so that they shall hold the valve open a longer or shorter time, as required.

Since compactness and lightness are not as essential as in portable, locomotive and marine engines, the parts are arranged in stationary engines with a view simply to securing efficiency, and the design is determined by circumstances. It was formerly usual to adopt the condensing engine in mills, and wherever a stationary engine was required. In Europe generally, and to some extent in the United States, where a supply of condensing water is obtainable, condens-

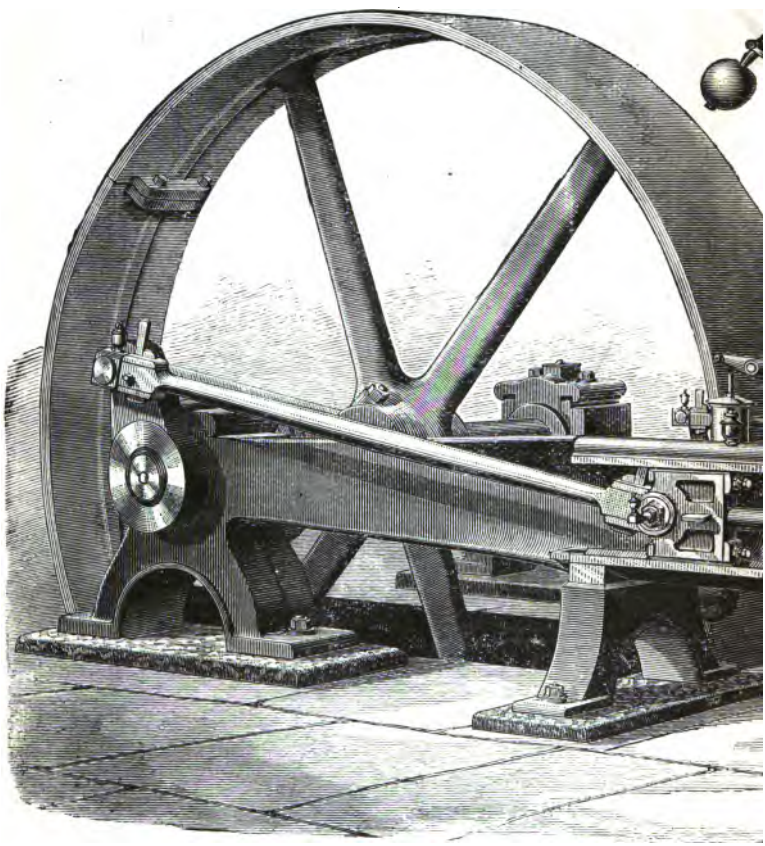
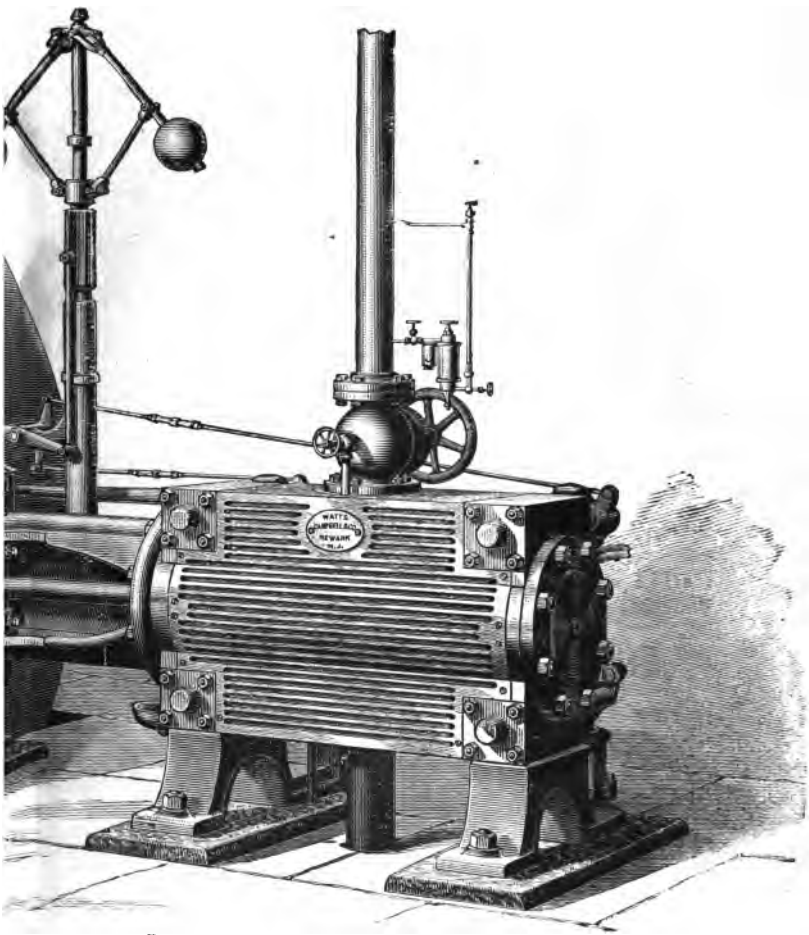


Fig. 9.—Improved Corliss Stea



STEAM-ENGINE.—FRONT VIEW. Page 57.

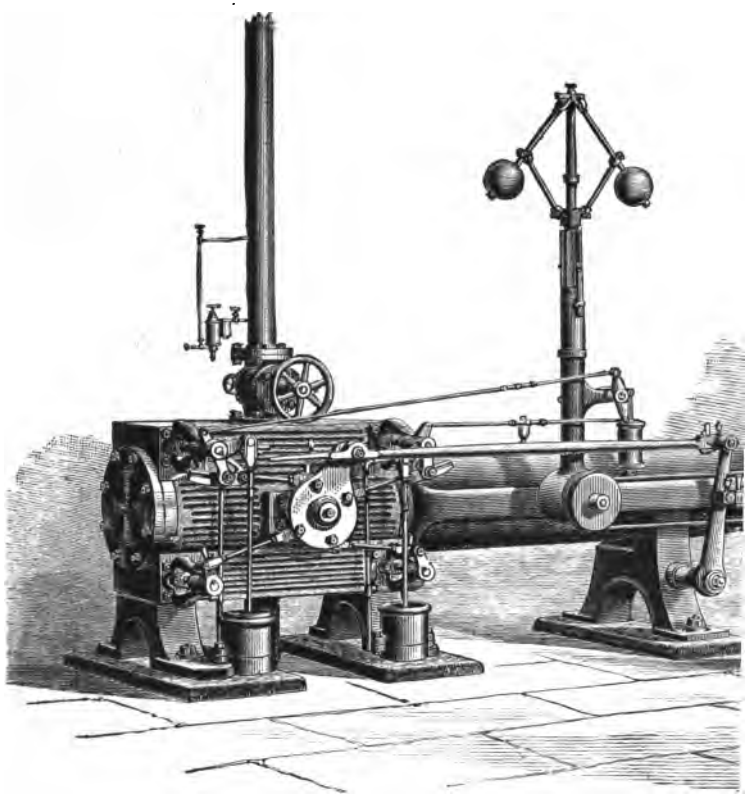
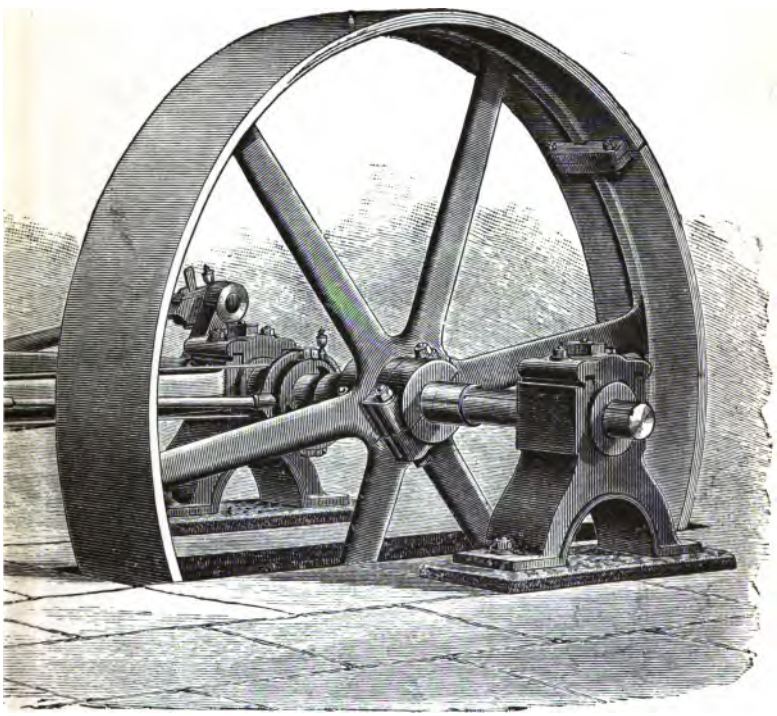


Fig. 10.—Improved Corliss St



M-ENGINE.—BACK VIEW. Page 57.

ing engines and moderate steam pressures are still employed. But this type of engine is gradually becoming superseded by the high pressure non-condensing engine, with considerable expansion, and with an expansion-gear in which the point of cut-off is determined by the governor. The best known engine of this class is the Corliss, which is very extensively used in the United States, and which has been copied very generally by European builders. Figs. 9 and 10 represent a Corliss Engine, as built by Watts, Campbell & Co., Newark, N. J.

The horizontal steam-cylinder is bolted firmly to the end of the frame, which is so formed as to transmit the strain to the main journal with the greatest directness. The frame carries the guides for the cross head, which are both in the same vertical plane. The valves are four in number, a steam and exhaust valve being placed at each end of the steam cylinder. Short steam passages are thus secured, and this diminution of clearance is a source of some economy.

Both sets of valves are driven by an eccentric operating a disk or wrist-plate, E (Fig. 11), which vibrates on a pin projecting from the cylinder. Short rods reaching from this wrist-plate to the several valves, DD, FF, move them with a peculiarly varying motion, opening and closing them rapidly, and moving them quite slowly when the port is either nearly open or almost closed. This effect is ingeniously secured by so placing the pins on the wrist-plate that their line of motion becomes nearly

transverse to the direction of the valve-links when the limit of movement is approached. The rods connecting the wrist-plate with the arms moving the steam-valves, have catches at their extremities, which are disengaged by coming in contact, as the arm swings around with the valve-stem, with a cam adjusted by the governor. This adjustment permits

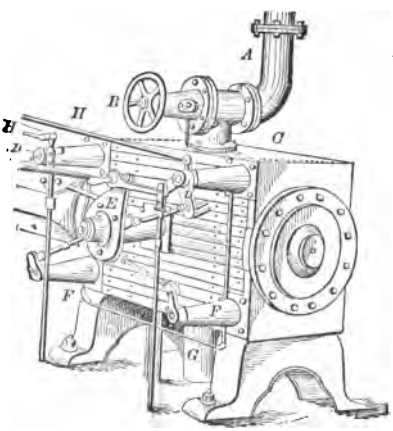


Fig. 11.—Corliss Engine Valve-Motion.

the steam to follow the piston farther when the engine is caused to "slow down," and thus tends to restore the proper speed. It disengages the steam-valve earlier, and expands the steam to a greater extent, when the engine begins to run above the proper speed. When the catch is thrown out, the valve is closed by a weight or strong spring. To prevent jar when the motion of the valve is checked, a "dash-

pot" is used, invented originally by F. E. Sickels. This is a vessel having a nicely-fitted piston, which

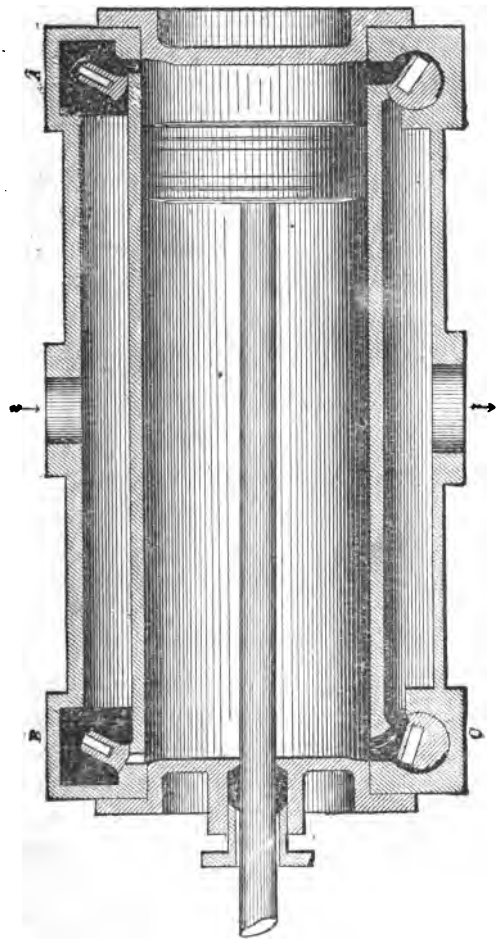


Fig. 12.—Corliss Engine.

is received by a "cushion" of water or air when the piston suddenly enters the cylinder at the end of the valve-movement. In the original water dash-pot of Sickels the cylinder is vertical, and the plunger or piston descends upon a small body of water confined in the base of the dash-pot. Corliss' air dash-pot is now often set horizontally.

Fig. 12 shows a sectional view of cylinder, piston and valves, so plainly that no further description is required. The piston is moving to the left —the steam-valve A, and the exhaust-valve C, both wide open, though the stroke has scarcely commenced, giving a full pressure of steam and a free exhaust.

The Greene Engine.

In the Greene steam-engine (Fig. 13) the valves are four in number, as in the Corliss. The cut-off gear consists of a bar, A, moved by the steam-eccentric in a direction parallel with the centre-line of the cylinder, and nearly coincident as to time with the piston. On this bar are tappets, CC, supported by springs and adjustable in height by the governor, G. These tappets engage the arms, BB, on the ends of rock-shafts, EE, which move the steam-valves, and remain in contact with them a longer or shorter time, and holding the valve open during a greater or less part of the piston-stroke, as the governor permits the tappets to rise with diminishing engine-speed, or forces them down as speed increases. The exhaust-valves are moved by an independent eccentric-rod,

which is itself moved by an eccentric set, as is usual with the Corliss and with other engines generally, at right angles with the crank. This engine, in con-

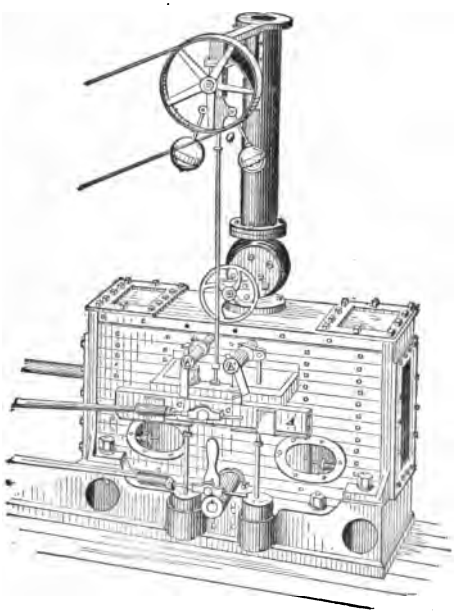


Fig. 13.—The Greene Engine.

sequence of the independence of the steam-eccentric, and of the contemporary movement of steam-valve motion and steam-piston, is capable of cutting off at any point from beginning to nearly the end of the stroke. The usual arrangement by which steam and exhaust valves are moved by the same eccentric, only permits expansion with the range from the beginning

to half-stroke. In the Corliss engine the latter construction is retained, with the object, in part, of securing a means of closing the valve by a "positive motion," should, by any accident, the closing not be effected by the weight or spring usually relied upon.

The characteristics of the American stationary engine, therefore, are high steam-pressure without condensation, an expansion valve-gear with drop cut-off adjustable by the governor, high piston-speed, and lightness combined with strength of construction. The pressure most commonly adopted in the boilers which furnish steam to this type of engine is from 75 to 80 pounds per square inch; but a pressure of 100 pounds is not unfrequently carried.

Woodbury, Booth & Pryor's Automatic Cut-off Engine.

Figs. 14 and 15 represent the Woodbury, Booth & Pryor Automatic Cut-off Engine. As will be observed, the bed plate is of the girder frame pattern, a design which has for several years become a favorite with engineers, both in this country and Europe. This perhaps arises from the fact that it affords the best disposition that can be made of the material to insure sufficient strength and rigidity, without extra weight of metal, as the center frame coincides with the plane of the line of strain, and with the center line of the engine. Besides, the strains induced by expansion and contraction can be more easily neutralized in this than in any other form. The frame is

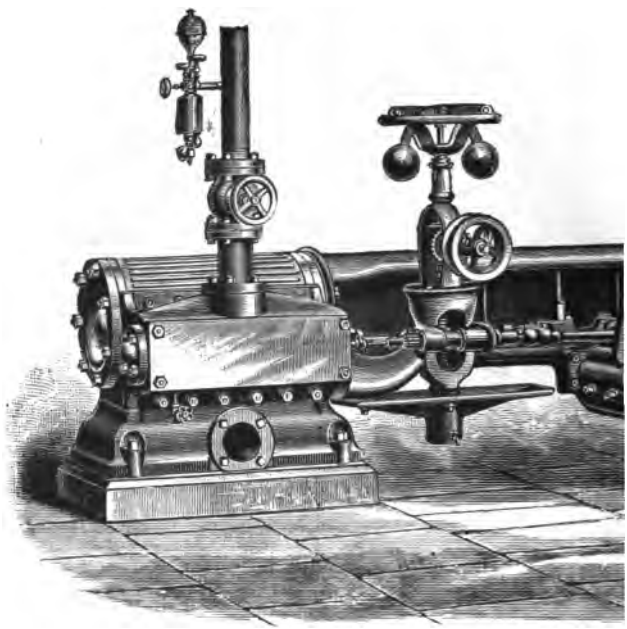
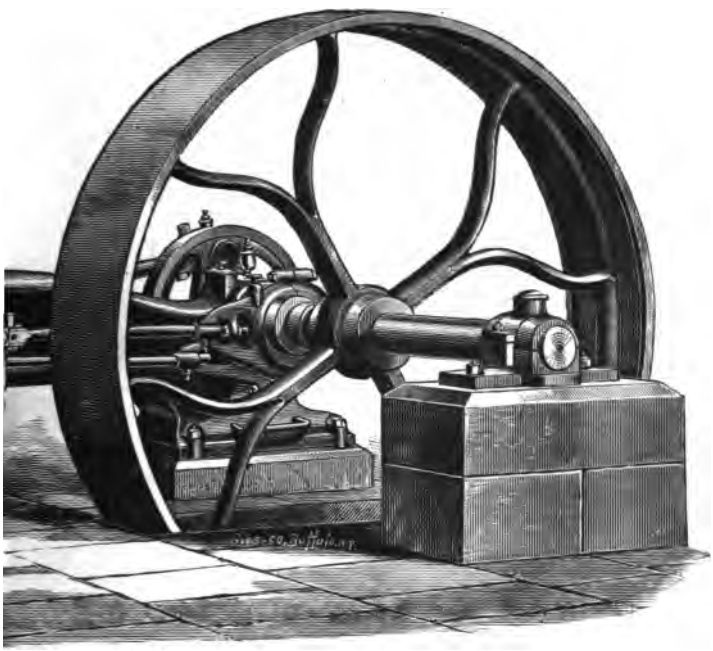


Fig. 14.—Back View of Woodbury, Boc



& PRYOR'S AUTOMATIC CUT-OFF ENGINE. Page 62.

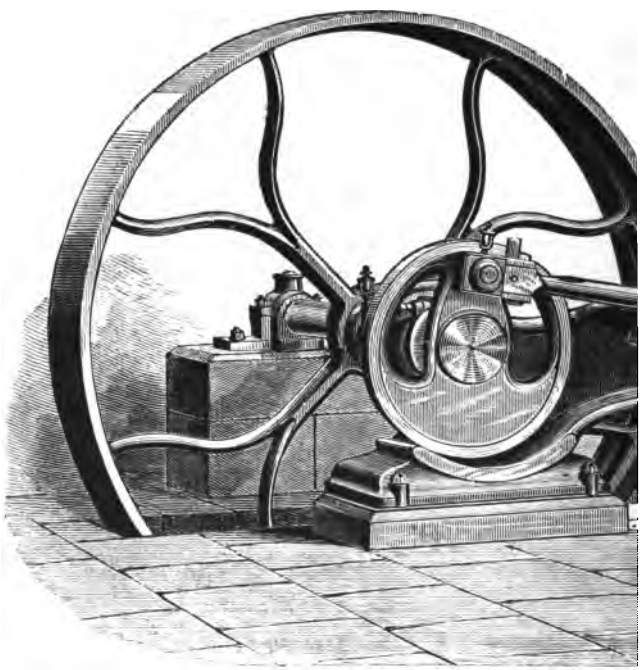
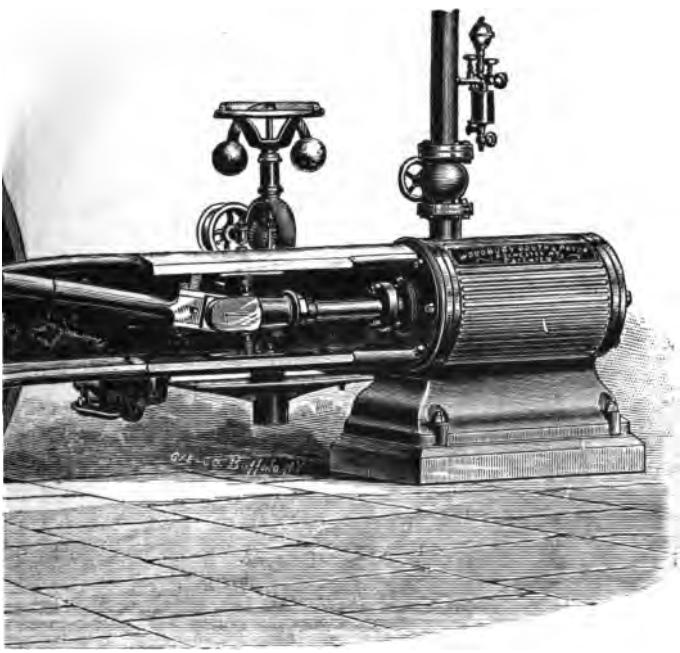


Fig. 15.—Front View of Woodbury, Booti



PRYOR'S AUTOMATIC CUT-OFF ENGINE. Page 62.

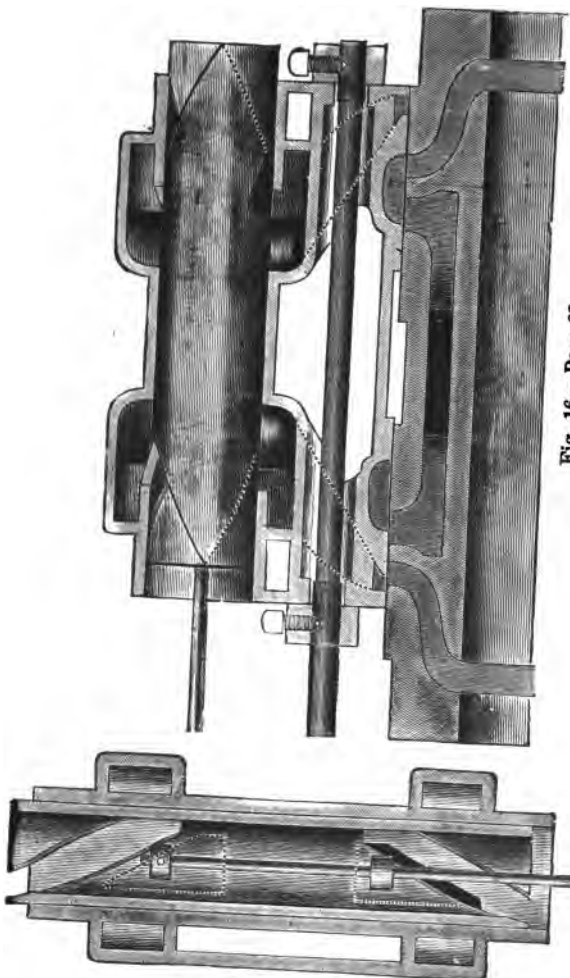


Fig. 16.—Page 63.

Fig. 17.—Page 63.

faced up at one end to receive the cylinder; the other end containing the back leg and pillow-block bearing. The cylinder, which is cast separate, forms a butt joint with the housing, and rests firmly on a handsomely designed hollow pedestal.

The admission and escape of the steam is accomplished by a double slide valve (Fig. 16), while the cut-off is effected by a semi-rotary valve (Fig. 17), located on the back of the steam-chest, directly over the main steam-valve; the cylinder in which it works being cast with the main valve. It will be noticed that it has diagonal admission edges, with ports to correspond, so that by revolving it in its seat, it is made to cut off sooner or later, the range being from zero or nothing to $\frac{3}{4}$ stroke, according to circumstances. The steam-valve receives its motion in the ordinary way, from an eccentric on the main shaft, and the cut-off by an independent eccentric, on the rod of which is a ball-and-socket joint, which allows the valve to rotate more or less, according to the requirements of load and pressure. The rotation, which never exceeds one-quarter of a revolution of the valve, is effected by a pinion on the eccentric rod, which gives motion to the cut-off, and into which a rack on the end of the governor spindle works, which places the cut-off completely under the control of the governor. It would be difficult to devise any mechanical arrangement more simple and effective than the cut-off of these engines; besides as the cut-off valve is balanced, and has a long bearing,

there is no liability of its wearing, or becoming leaky.

The governor, which is of the fly-ball or centrifugal pattern, though of peculiar design, is admirably adapted to control the speed of these engines, as it is very powerful and sensitive, and holds the cut-off valve under complete control, under all circumstances. The arms of the governor have their fulcrum in an ornamental ring, resting on four brackets, attached to the vertical column, and, as the tilts of the arms extend across the center, and have their points of suspension on the side opposite to that of the balls, they acquire an extensive range of movement, with a small variation of speed. The governor is also provided with a dash-pot, on the lower end of the spindle, which insures a smooth, noiseless and uniform movement, both in raising and lowering. A very important and agreeable feature of these engines is the absence of all complications in the valves and valve-gear; there being only two valves, each consisting of but one piece, and all the connections and arrangements for adjustment being easy of access. Each engine is provided with a standard gauge, by which the valves may at any time, in case of wear, be adjusted to their original position, and rendered perfectly steam-tight, by any person of ordinary intelligence, which obviates a difficulty often experienced in adjusting the valves of some other steam-engines. Besides, as the cut-off valve and valve-seat are cylindrical in form, they can be repaired or re-

newed at a very trifling cost, or without the use of any special tools.

Some of the advantages of the Woodbury, Booth & Pryor engines are, that they are handsome in design and convenient and simple in arrangement; that the ports are located sufficiently low in the walls of the cylinder to secure perfect drainage, and obviate the liability of the cylinder or piston to become fractured by an accumulation of the water of condensation; that drip cocks may be dispensed with altogether; that the pistons have the most approved and convenient metallic spring packing; that the cylinders are handsomely jacketted, which adds to their economy by preventing radiation and condensation; that the cross head is provided with convenient arrangements for easy and accurate adjustment; that the cranks are accurately counterbalanced, which is a consideration of great importance, especially in engines traveling at a high rate of piston speed; that the crank pins have a hollow cellar, or receptacle in the center, for the purpose of containing the lubricating material which prevents the possibility of heating; that the bottom flange of the bed plate or housing is so designed as to form a trough, which extends from the cylinder head to the outer end of the pillow block, for the purpose of catching the drips from the cross head, crank, and eccentrics, (those from the governor and valve spindles being conducted into the dash-pots); that the valve and piston rods, wrists, crank pins, and crank shafts, are

made of steel, thus diminishing the liability to wear, and likewise the expense of repairs; that the connecting rods and main journal boxes are of ample proportions, made of the best material, and accurately fitted, thus insuring durability.

The Wheelock Engine.

The economy of variable or automatic cut-off engines has been so well established, that no remarks in favor of the general system are required. To overcome the objection of complication for common use is a desideratum well attained in the machine herewith shown.

By reducing the number of parts and placing all the mechanism for operating the valves on the outside of the steam-chest, every defect may be at once detected.

Valves are used, which are suspended on hardened steel trunnions, or stems, and hardened steel bushings, and are located directly under the bore of the cylinder at each end, thereby reducing the clearance to the smallest possible amount. The valves and seats are made tapering in their general diameter, and the pressure of steam comes on one side, which also acts to keep the collar in contact with the sleeve. Steam is admitted and exhausted by a single valve, and any variation of the load is at once communicated through the action of the governor, which has entire control over two cut-off valves, or wipers, by a simple mechanism, the construction of which is such

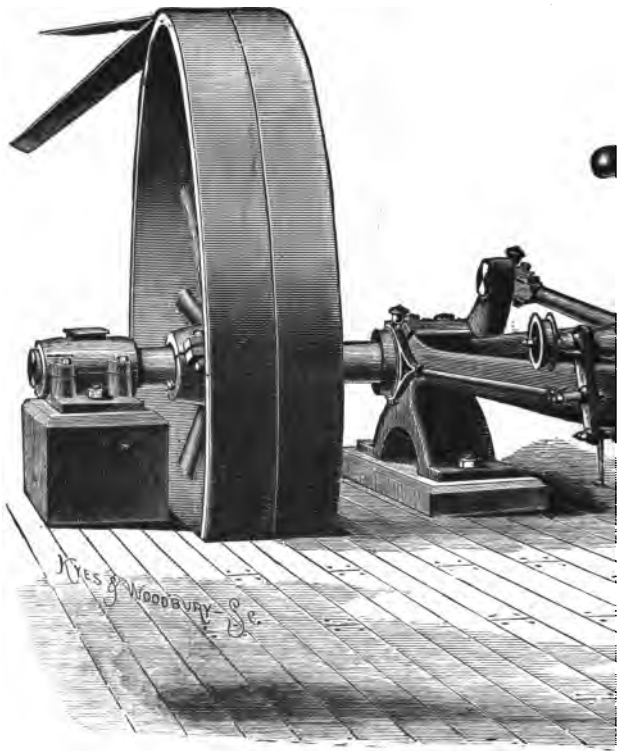
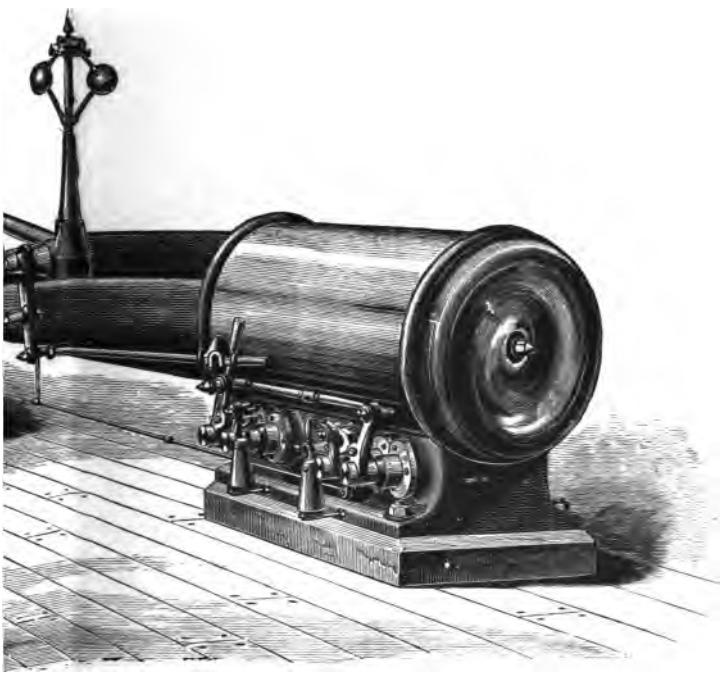


Fig. 18.—The Whe



WHEELOCK ENGINE. Page 66.

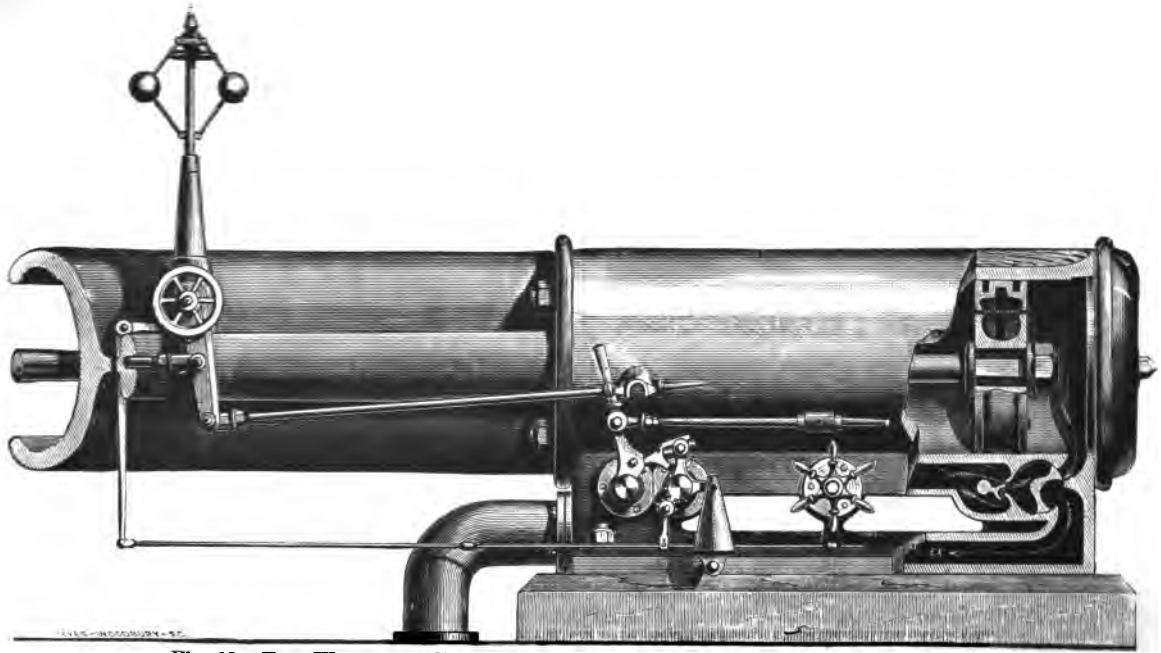


Fig. 19.—THE WHEELOCK ENGINE. (*Section through Cylinder and Valves.*) Page 67.

(Cylinder and Valves.) Page 67.

as to insure entire uniformity of speed under extreme variation of load. A cavity in face of the cut-off valves allows a double admission and closing. A very perfect result is claimed as due to the fact, that the valves are suspended on the hardened steel trunnions and bushings, thereby maintaining the valve in a central position. Attention is called to the fact that the cut-off does not control the time of admission or lead to the cylinder, but is well open before the main valve is ready to open the induction port. This is claimed as a great advantage, especially where steam follows but a small portion of the stroke. The explanation is, that if the cut-off opens but a crack, as in cases where the lead is controlled by the cut-off, the mechanism is not sufficient to close it, and steam sizzles through during the whole stroke, thereby making speed irregular. The valve-gear is constructed in the simplest form of the ordinary eccentric rod, and is made to disengage at the pleasure of the engineer, by which result the engine can be worked by hand, either forward or backward, with perfect ease, a point very desirable in practice.

By reference to Fig. 19, showing valve gear, it will be noticed that the cut-off is worked from the main valve crank. The pin being an eccentric bolt makes adjustment very handy. This attachment produces the celebrated wrist-plate motion, without its complications.

The entire adjustability of the valves to their seats is secured by a peculiar arrangement of the steel

bushings (which can be driven in or out as required), the inner end forming a joint against the steel valve-stem or trunnion, entirely obviating the necessity of any stuffing-box. These steel stems have been found in practice to wear endwise in about equal ratio with the surface of the valves and their seats; and as the valves are suspended with the surfaces in but slight contact, while the pressure inclines the valves to their seats, great durability is obtained. The steam-chest is located underneath, and forms a part of the cylinder, as is also the exhaust passage. The latter is entirely separated from the steam-chest, and in no way influences the live steam, while easily disposing of any accumulation of water.

The cylinder has but two ports, and the valves being suspended, do not gouge out the seats, nor do the seats need to be recessed. The object of this construction is to get the effect of steam balancing without the objections that apply to that method.

In the production of the Wheelock engine, it has been the aim of the manufacturer to produce an engine with the most advantages and the fewest disadvantages to be found in any machine now offered to the public. His success in that direction may be measured by the high position the engine has attained where it is known.

The arrangement of the valves not only reduces the clearance to a minimum, but guards against a waste of steam through the exhaust port, if there be a leakage in the cut-off valve.

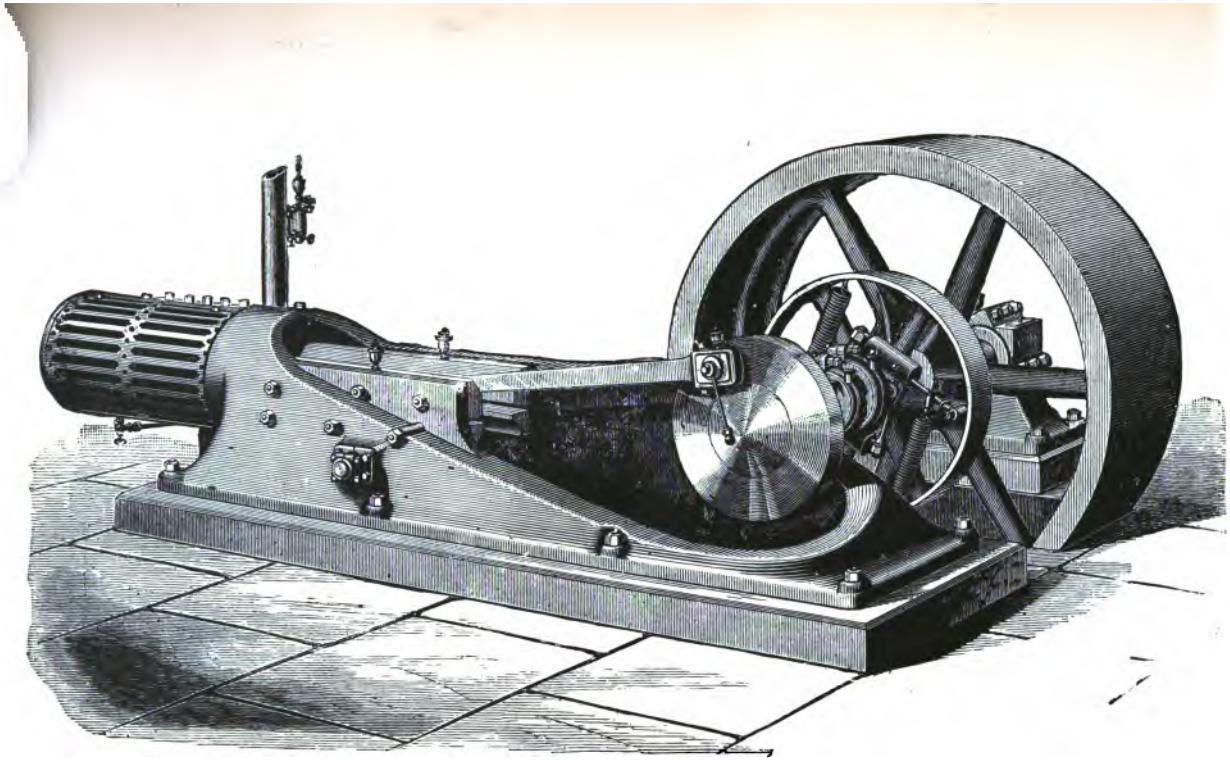


Fig. 20.—Front View of Hartford Automatic Engine. Page 69.

The cylinders of these engines are fitted with the Wheelock piston and steam packing, which have shown gratifying results in use during sixteen years.

The stop motion in use in these engines effectually prevents the engine from running too fast, in case of accident to the governor.

The Buckeye Automatic Engine.

Figs. 20 and 21 show the front and back views, Fig. 22 a sectional view through cylinder and valves, and Fig. 23 the governor, of the celebrated Buckeye engine as constructed by the Hartford Engineering Co., Hartford, Conn., and known to the public as "The Hartford Automatic Engine." It is a new design, based on the Buckeye or Thompson system of valve gear.

It will be seen that the bed is of the Tangye type, and has in its design received the particular attention so necessary in high-speed practice. It is very heavy, and has a notably broad bearing surface on the foundation; and, unlike most other beds of this class, has a large amount of metal judiciously distributed above the centre line, so as to transmit the strains in a direct line from the cylinder to the bearing of the main pillow-block. The end of the bed to which the cylinder is attached is strengthened by a massive hood, and further rigidity is obtained by a diagonal rib down the front. Particular attention seems to have been paid to the concentration and distribution

of metal at the main bearing, and the bed is hollowed out in such a way as to catch and retain the drip. On the whole, it presents a harmonious distribution of metal, representing strength and good taste.

The piston, which is made light and in one piece, has a depth equal to one-half its diameter, whereby ample wearing surface is obtained, and is packed with two simple spring rings, which require no adjustment. Loose rings, H H, in the stuffing box, are arranged to give the piston-rod freedom, thereby preventing cutting.

The cross head is of the locomotive type, fitted with a steel pin and gun metal shoes, and is split and finished in such a way that when bolted together it binds so tightly on the thread of the rod as to require no jam nut, while at the same time it can be readily loosened to admit of adjusting the length. Both guides are adjustable for lining the cross head.

The connecting rod is finished flat, and gradually increases in the area of its cross section from the cross head to the crank pin end, it being intended, in this respect, to proportion it for its entire length with reference to the strains to which it is subjected.

The crank pin is of steel, three-tenths of the diameter of the cylinder both in length and diameter, and is accurately finished by grinding on dead centres. The crank-pin boxes are of hard metal, lined with babbitt, and are fitted to a solid head on the connecting-rod, in which they are adjusted by a wedge and screw.

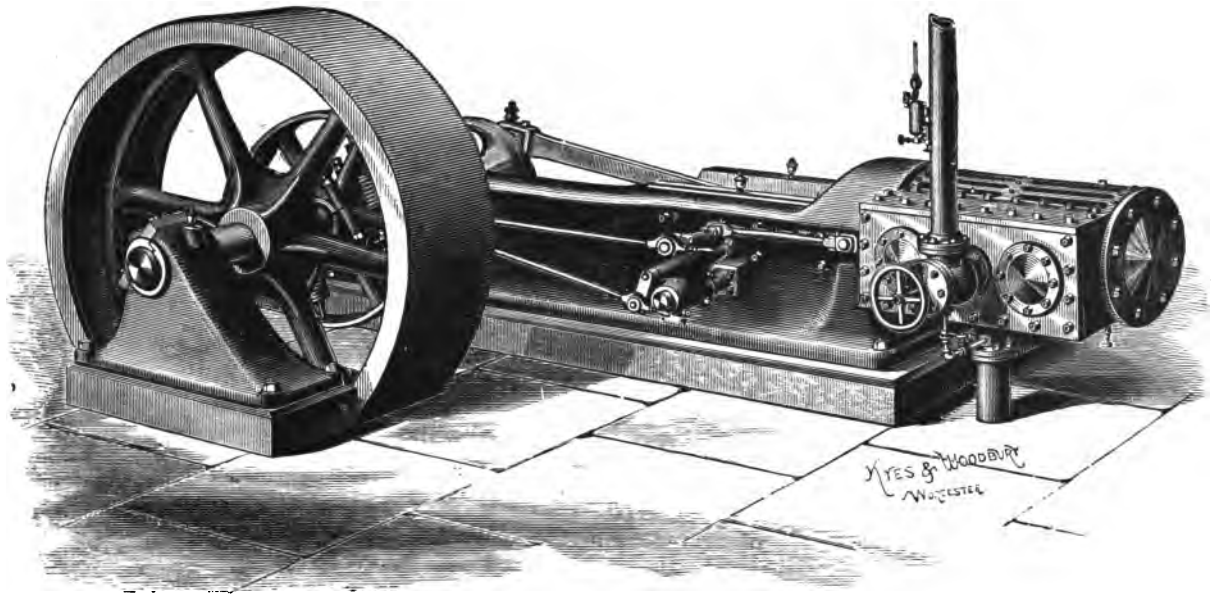


Fig. 21.—Back View of Hartford Automatic Engine. Page 70.

The crank is a counterbalanced disc, and the shaft is of hammered scrap iron, in diameter equal to one-half the bore of the cylinder, and with journals two diameters in length.

The main eccentric is adjustable on the shaft, so that the compression can be controlled to insure smooth running.

All bearings are provided with two means of lubrication: the one automatic, and answering all ordinary purposes, while the other is positive, and is for use in case of the choking or clogging of the automatic devices. Throughout there are ample and simple means of adjustment and compensation for wear.

It is the claim of the company that in design and workmanship this engine is a representative of the best practice of the day. Their practice comprehends moderately high speed—from 100 to 200 revolutions, according to size—steam-pressure of about 80 lbs. and fairly heavy loads—corresponding to a cut-off at about $\frac{1}{4}$ stroke.

Valves and Valve Motion.

The live steam enters at A, Fig. 22, whence it passes through passages *a a''* and the open pistons *D D*, into the interior of the box slide-valve *B B*, as shown by the arrows. From the box-valve the steam is admitted to the cylinder through ports *b b* in its face, as these ports are alternately brought to coincide with the cylinder ports.

The cut-off valve, which consists of two light plates *C c* connected by rods *C'*, works on seats inside of the main valve, as shown, and alternately covers the ports leading to the cylinder. The cut-off valve-stem *g* works through the hollow stem *G* of the main valve. The exhaust takes place at the end of the valve (as shown by arrow on right) into the valve-chest and into the exhaust pipe *F* below.

Among the new features since the first introduction of the engine, are the relief chambers *e e* in valve-seat. To explain the use of these, it must be understood that, the steam being *inside* of the slide-valve instead of *around* it (as with the common slide-valve), the tendency of the pressure of the steam in the ports *b b* and in the cylinder is to force the valve from its seat, but this tendency is counteracted by the pressure of the entering steam; this pressure being proportioned to the area of the pistons or equilibrium rings *D d, D d.* These pistons are made large enough to hold the valve to its seat at the moment of admission (as at left end of valve, Fig. 22) when the tendency to leave the seat is greatest, being then equal to the pressure of the steam on the united area of both the port *b* in the valve, and the port in the cylinder. At other times the pressure on the seat would be greater than necessary; but to prevent such undue pressure, live steam is admitted to the relief chambers *e e* through small holes *f f* in the face of the valve just after it is exhausted from the cylinder, as shown at the right-hand end of valve, Fig. 22, and in turn

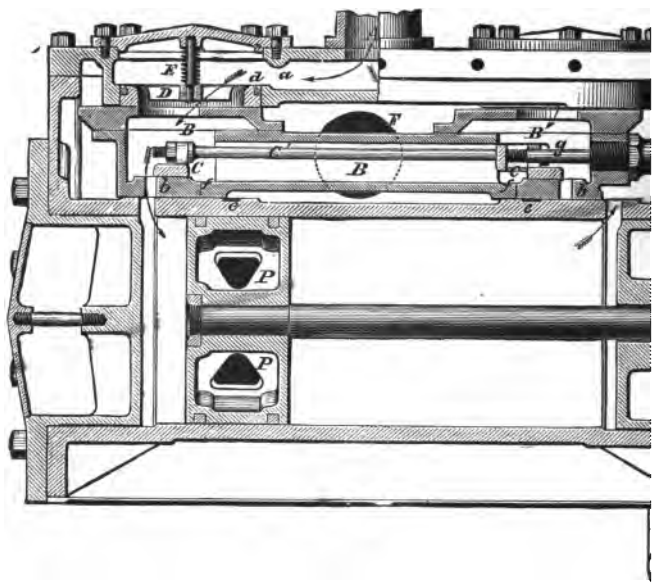
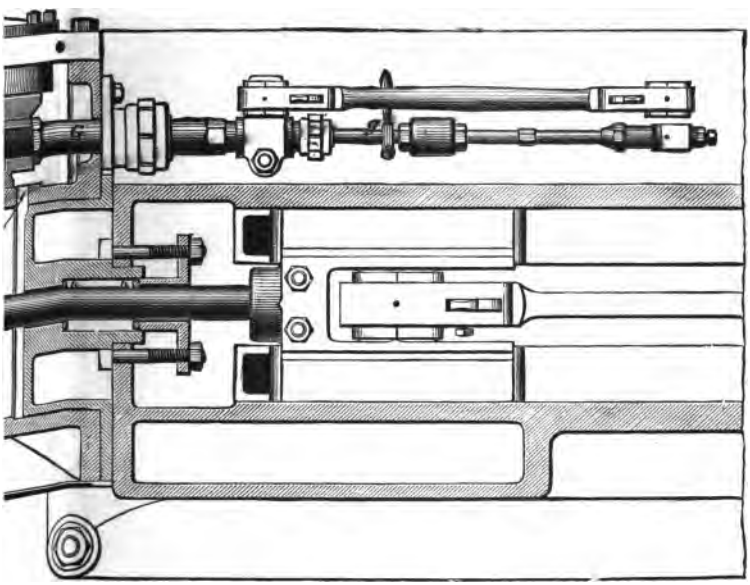


Fig. 22.—SECTION OF



N OF CYLINDER AND VALVES. Page 72.

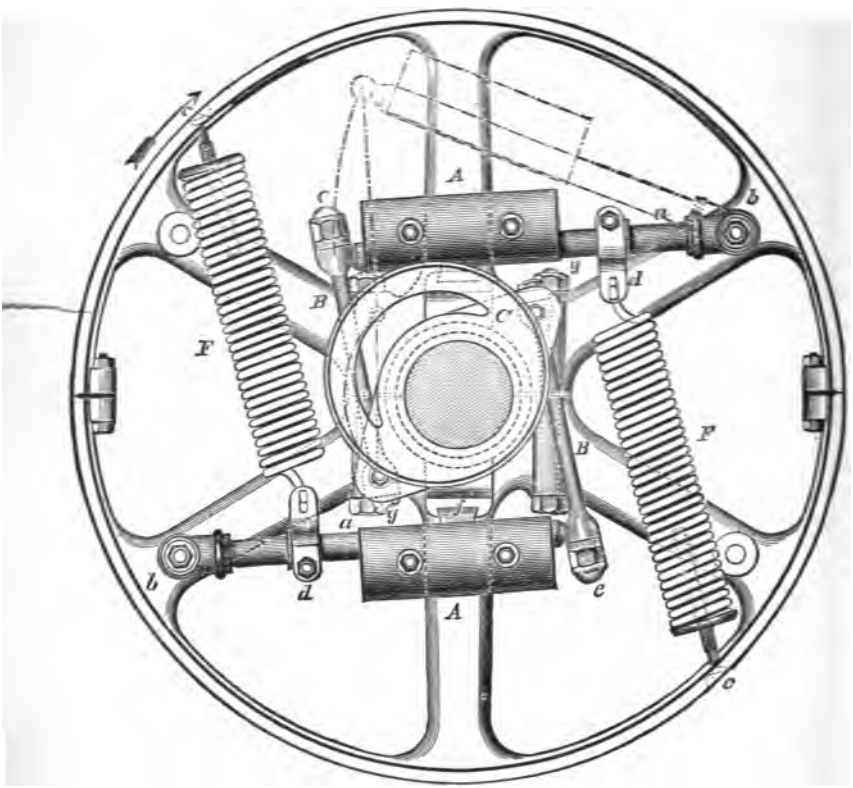


Fig. 23.—Buckeye Automatic Engine—the Governor. Page 73.

exhausted from them, as shown at the left, just before steam is admitted to the cylinder. The result is a moderate and very nearly a uniform pressure on the seats at all points of travel, and the arrangement also greatly assists in the proper distribution of lubrication.

Another recent improvement consists in placing the equilibrium rings in the back cover of the valve-chest, instead of in the cover of the valve, as formerly. The value of this improvement consists mainly in its rendering the equilibrium rings accessible without removing the valve.

The Governor.

The remarkable simplicity of this device will be apparent on inspection of Fig. 23. Two levers, *a a*, are pivoted to the arms of the containing case at one of their ends, as at *b*, while the movable ends are connected by links *B B* to ears or flanges on the sleeve of the loose eccentric *C*, so that their outward movement in obedience to centrifugal force (as indicated by dotted lines) advances the eccentric forward in the direction of revolution. Springs *F F*, of tempered steel wire, furnish the centripetal force. The tension of the springs is adjustable by a screw from the outside of the case at *c*, as shown. The proper amount of tension in any given case is that which will confine the percentage of variation due to changes of load and pressure within as narrow limits as may be desirable—the greater the tension the less

the variation—so that, if desirable, it may be reduced until it is imperceptible. *In fact it is possible to obtain as close regulation with it as the nature of the load and other conditions outside of the construction of the engine would permit with any known method of regulation.* The proper speed is obtained by adding more or less weight at *A*, or within certain limits by shifting the weights along the levers. The weights *A* are cored out in pockets, which may be filled with lead. As a rule, the tension is not to be changed to effect changes of speed, though slight changes of speed may properly enough be so effected, provided no objectionable degree of change of sensitiveness results.

The case is in halves, and is clamped to the shaft by the pinch bolts *g*. Rubber buffers at *e* and *f* cushion the levers in their extreme positions. Both ends of the links *B B* are ball-and-socket joints, to prevent binding. The spring hooks *d* are adjustable along the levers, but once set should not be disturbed. Their position is one-third of the length of the lever, *a*, from the pin *b*.

The parts are shown in their proper position for motion in the direction of arrow; for motion in the opposite direction, the levers are pivoted to the other arms of the case, and the springs are reversed. All of these governors are so constructed that this change can readily be made at any time.

The Range of Adjustment.

When the *earliest* cut-off that the action of the regulator can produce is no earlier than is necessary to restrain the engine under its lightest load and greatest steam-pressure, the *latest* will be at $\frac{5}{8}$ to $\frac{3}{4}$ of the stroke, where it meets the fixed cut-off of the main valve, due to its lap and angular advance, *and this whole range of adjustment is under complete control of the governor*. To appreciate the value of this feature, it should be understood that, with single eccentric releasing gear movements, the governor can only control the time of release during the opening movement of the valve, which necessarily terminates before mid-stroke, so that if the release is not effected before mid-stroke, it will not take place at all during that stroke, thus causing extravagant expenditure of steam, and spasmodic irregularities in the motion.

The "Wright Patent Steam-Engine," with Automatic Cut-Off Valve Gear.

Fig. 24 shows the steam-side, with cut-off valve gear. The eye is immediately attracted to the peculiar construction of the bed-plate frame. The portion of the frame which, in ordinary engines, is devoted to the usual flat slides, consists of a hollow cylinder arranged concentrically with the steam-cylinder, and serves as a guide for the cross-head, the guiding cylinder being simply bored out to receive the cross-head. There are lateral openings in this cylindrical guiding portion of the frame, in order

that access may be had to the cross-heads and stuffing-box of the piston-rod. It will be readily understood by those familiar with the costly fitting and other preparations demanded by the slides of ordinary horizontal engines, that this combination conduces to simplicity, strength, and economy in the construction of the frame. From the front of the guiding cylinder, or slides, to the point where it meets the base, the frame is made in the form of an inclined concave-convex trough, deep enough to permit free movement of the connecting-rods. The trough has the upper edge of one side continued in a plane coinciding with the center of the cylinder from the latter to the enlargement, for receiving the bearing of the crank-shaft; the opposite side of the trough extending from the guiding cylinder with a gradually descending curve to the base, into the upper portion of which it merges.

In horizontal engines there is necessarily an excessive lateral strain on the frame between the cross-head guide and the crank-shaft.

This strain is effectually resisted by the proper distribution of the material in the construction of this bed-plate.

The steam-cylinder itself rests on a separate bed-plate, to which it is securely bolted, the bottom of which is at the same level with the pillow-block and the bed-plate. This cylinder foot carries all necessary rocker-shafts for the valve-gear. There are four valves, known as the gridiron slide-valves, which

work vertically in the chest cast with the cylinder, two upon one side of the cylinder being for induction, or cut-off, and two upon the opposite side being for eduction, or exhaust steam.

All valve motion is derived from a single eccentric, which operates levers so arranged as to give quick opening movement to valves when opening, and also a very slow movement when valves are lapped. The location of all these valve-faces close to the bore of cylinder insures the least possible amount of clearances. The steam valve-stems are fastened in yokes, which have at their lower ends plungers fitted in dash-pots, the same acting as guides; the yokes are operated by steel slides fitted through the end of hollow rocker-arms, and which act upon the swinging toes held in the yokes, the said slides having a diagonal slot, in which works a feather, this feather being made on a rod which has a longitudinal movement through the hollow rocker-arm, and to which the governor is connected. By this longitudinal motion, and through the diagonal feather and slot, the slide is automatically set, to engage more or less with the swinging toes, and which gives the valve its proper lift, and liberates upon the chord of the arch. The governor itself stands on a bracket or shelf, cast on the slide part of the bed-plate, and the governor-rod is connected to a lever, which is fastened to the governor-shaft. This same shaft carries two forked arms, which take hold of the small rods running through the hollow rocker-shafts. The rods are

enlarged at their other ends, where they carry the adjustable slides mentioned before.

The advantages in this arrangement of valves and valve-gearing are, easy accessibility to each valve, by the simple removal of a bonnet; and the very important and desirable fact is, that the whole of the valve-gear and governor connections is outside of the steam-chests, where any derangement can be at once seen and rectified.

The steam-piston is fitted with steam-packing rings, and a brass shoe reaching around the lower half of the piston, and is adjustable by set-screws to carry the weight of the piston. The piston-rod, crank and cross-head, pins, valve-stems, and all smaller wrist-pins, and all heads of connections, are made of steel; all connections have adjustable brass boxes. The cross-head, which is made of cast-iron, has a large shoe at the top and bottom, lined with anti-friction metal, fitted to the bore of the slide, and is adjustable by wedges and set-screws to take up the wear.

The connecting-rod is of best hammered wrought-iron, with composition boxes at each end; the crank-shaft is made of best hammered wrought-iron, has long bearings, one in the main bed-plate, and one in an outside pillow-block, both lined with anti-friction metal, and the main bearing with adjustable side boxes.

This engine will maintain its uniform speed with a very slight variation, changing between its max-

imum and minimum load as near as can be attained by any automatic regulation; it will carry out the law of expansion according to the theory established by science as nearly perfect as has ever been done; and by its superiority in proportions, compactness, durability, and arrangement of parts for accessibility for repairs, commends itself to all practical engineers.

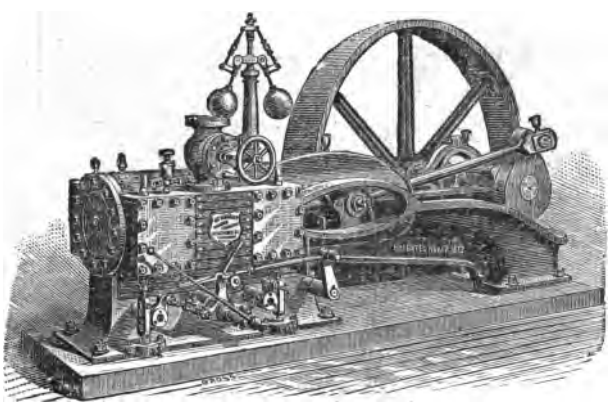


Fig. 24.

These engines are built exclusively at the Wright Steam-Engine Works, Newburgh, N. Y., under the personal supervision of Mr. William Wright, the inventor and patentee of the engine.

The Watertown Automatic Cut-off Engine.

Fig. 25 gives a general view of the Watertown Engine, and Fig. 26 shows the cut-off valve. It will

be seen that there are two eccentrics, and therefore two valves. The eccentric nearest the pillow-block is connected to the main valve, which is of the ordinary pattern, with this exception, that the steam instead of passing the edge of the valve, is taken through it, by means of the ports C and D, shown in Fig. 26.

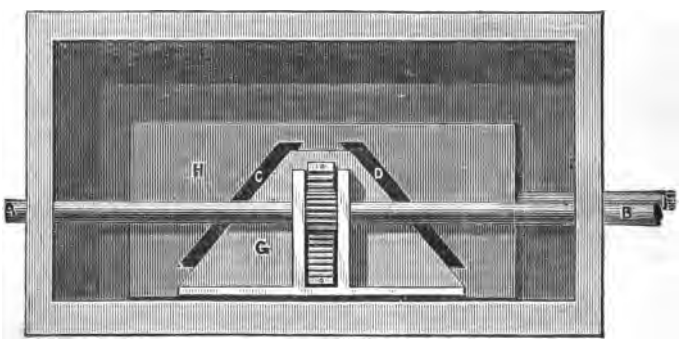


Fig. 26.

H represents the back of the main valve, which is also the seat of the cut-off valve G. F represents the stem of the main valve, and B the stem of the cut-off which is continued on through the end of the steam-chest, and is held steady while the engine is working by means of a horn at A. The reader will notice that there is a rack cut in the back of the cut-off valve, which engages the teeth of a small gear on the valve-stem, and from this device will at once come to the conclusion that the adjustment of the cut-off is accomplished by rolling the valve-stem. This, as a

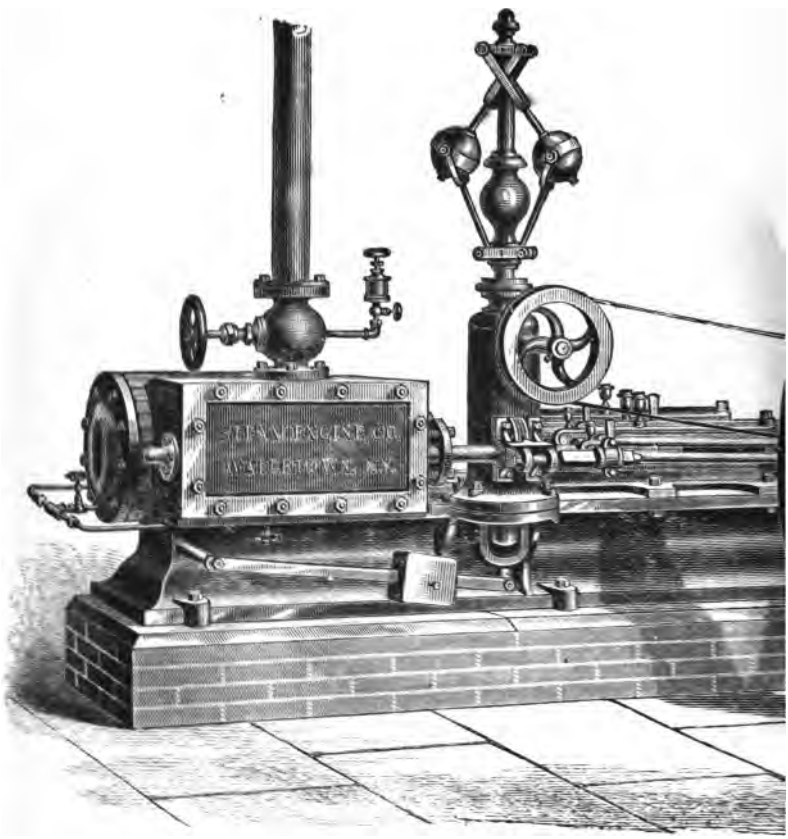
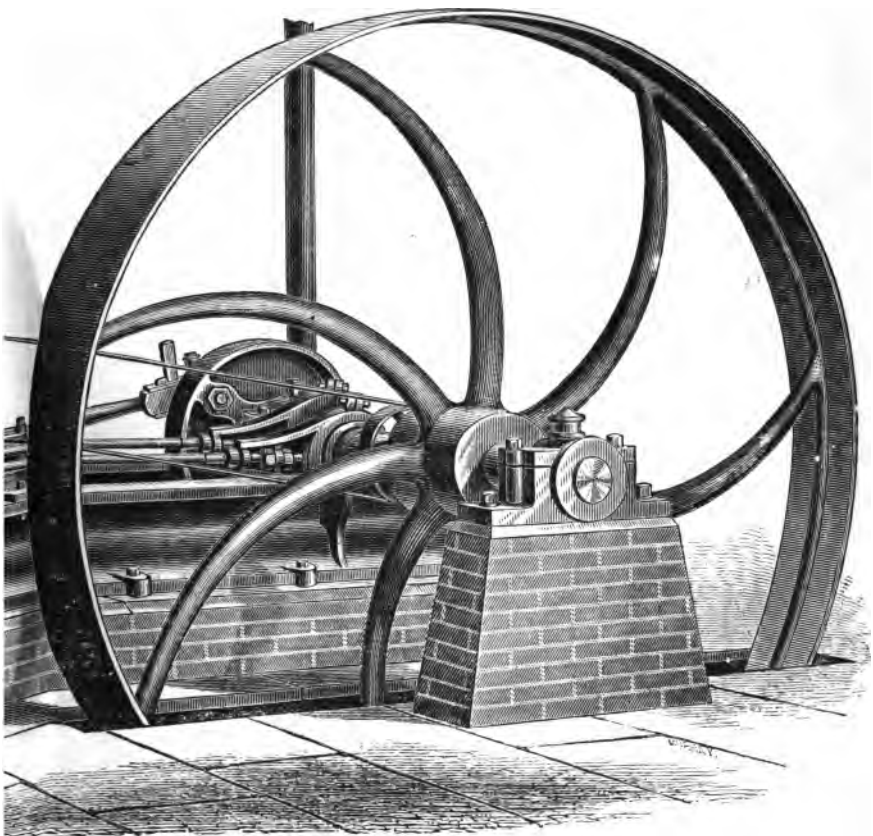


Fig. 25.—The Watertown A



AUTOMATIC CUT-OFF ENGINE. Page 80.

matter of course, will raise and lower the cut-off valve by means of the rack and pinion, thereby opening or closing the ports.

Directly under the governor there is a disc on the valve-stem, with teeth cut on the periphery about half the circumference, and these teeth engage a rack connected with the governor spindle; consequently, as the balls of the governor rise and fall, a proportional motion will be transmitted to the cut-off valve.

In order to make this motion positive and reliable at all times, an important improvement has been made in the manner of suspending the governor balls. The point of suspension, instead of being on the same side of the spindle as the ball, is carried to the opposite side, thereby greatly increasing the power and sensitiveness of the governor.

To determine the point at which the engine is cutting off while running, the plain part of the disc which is connected with the governor and valve-stem, has marks and figures upon it, each mark indicating a point in the length of the stroke. There is a point which coincides with these marks. A glance at this device will show at once the point at which the cut-off takes place. To increase or diminish the speed, a counter-weight is attached to the end of the governor spindle, under the steam-chest. These engines are also built with a plain slide-valve, and with cut-off adjustable by hand.

The bed-plates are very solid, heavy, and sub-

stantial. The cylinder is jacketed to prevent radiation. The piston consists of three rings and springs. The piston-rod is screwed to the cross-head and secured by a jam-nut, admitting of adjustment at any time, as it wears.

The steam-chest is full length of the cylinder, reducing the clearance space to a minimum. These engines are justly numbered among the "standard" engines of this country.

The Economy of a Steam-Engine.

This is expressed in terms of the number of pounds of water consumed per horse-power (H. P.) per hour. The rate of *water* consumption is the only intelligible expression for the engine alone, as the amount of fuel used must depend largely upon the kind of boiler and its condition, the manner in which it is set and fired, the quality of the fuel, the draft, and numerous other conditions, for which the engine is in no way responsible.

This rate may be found by the following rule: Divide the constant number 859,375 by the *volume* of steam at the terminal pressure, and by the mean effective pressure. The quotient will be the desired rate.

With non-condensing engines, the best possible economy, *with a given boiler pressure*, is theoretically obtained when the full pressure is admitted to the cylinder up to the point of the cut-off, and the degree of resulting expansion is such that the ter-

minal pressure is lowered to, or nearly to, that of the atmosphere; provided that the construction of the engine is such as to combine with a free exhaust and induction the least possible loss from clearance, friction, leakage, and condensation. Under such conditions the steam may expanded *until there is no more work in it*, and no higher economy is possible with the given boiler pressure without a condenser.

The best theoretical economy possible *with a given load and boiler pressure*, is obtained when the cut-off takes place as early as possible in the stroke, consistent with obtaining the average pressure necessary to do the work and maintain the proper speed.

The effect of a condenser should be to make available about 10 pounds more mean effective pressure, with the same terminal pressure; or to give the same mean effective pressure with a correspondingly less terminal pressure. When the load on the engine requires 20 pounds M. E. P., the condenser does half the work; at 30 pounds, one-third of the work; at 40 pounds, one-fourth, and so on. It is safe to assume that practically the condenser will save from one-fourth to one-third of the fuel, and it can be applied to any engine, cut-off or throttling, where a sufficient supply of water is available.

The Buckeye Engine Co., of Salem, Ohio, has introduced a very excellent type of condenser for stationary purposes. It is both simple and effective, contains no valves, and cannot get flooded with

water. Those who have used them speak in the highest terms of their efficiency.

Condensers.

Jet condensers should have one cubic foot of capacity for each indicated horse-power. Surface condensers working with engines cutting off at half-stroke should have three feet of tube surface per indicated horse-power. Very small tubes, such as $\frac{1}{2}$ in. external diameter, are apt to crack; $\frac{5}{8}$ or $\frac{3}{4}$ are preferable, with spaces between of $\frac{1}{4}$ in. to $\frac{1}{2}$ in.; $\frac{5}{8}$ tubes are generally pitched 1 in. apart; $\frac{3}{4}$ tubes are generally pitched $1\frac{1}{8}$ in. apart. Condenser tubes are usually eight feet long, as they are manufactured to 16 feet lengths (unless specially ordered); they cut into two lengths without waste or extra cost. Solid drawn tubes are of inferior metal to lap or brazed tubes.

Useful Notes for Calculations Concerning Pumps.

In the year 1826 the imperial standard pound was adopted from avoirdupois weight. It was defined to be the weight of $\frac{1}{10}$th part of an imperial gallon of pure water at 62° F. and 30 in. of barometer. Therefore:

A gallon of pure or distilled water weighs 10 pounds.

A cubic foot of water weighs 997.137 ounces, or $62\frac{1}{2}$ pounds; or, approximately, about 1000 ounces, or 625 pounds, or a little over $\frac{1}{2}$ cwt.

A cubic foot of water contains 6.25 gallons; or, as an aid to memory, pounds in a cubic foot divided by 10 give gallons, the figures being the same, with the decimal point removed one figure to the left.

A pint of water weighs about 20 ounces, or 1¼ pounds; or, as stated by the old rhyme,

"A pint of pure water
Weighs a pound and a quarter."

India-Rubber Valves, for Circulating and Air-Pumps.

Diameter.		Thickness.
4 in.	=	⅜ in.
5 "	=	$\frac{7}{16}$ "
6 " to 7½ in.	=	½ "
7½ " to 8¾ "	=	$\frac{9}{16}$ "
9 " to 10½ "	=	⅝ "
10½ " to 12 "	=	$\frac{11}{16}$ "

The hole in the centre of valve to be $\frac{1}{16}$ in. larger than the diameter of the stud.

Value of High Rotative Speeds.

As a factor of *economy*, piston speed of itself has no value. That which has value, is *piston speed got by rotative speed.*

We could get piston speed, and consequently power, by increasing the length of stroke, without increasing the number of revolutions. But such a proceeding would diminish rather than improve the economy, for the following reason: It is evident that the *longer time* steam remains in contact with a cooler surface, the more will it be condensed. *To use a little steam at a time, to use it very quickly, and to keep it hot*, is the fundamental principle of high rotative speeds, than which there is nothing more practically important in Steam-Engineering. We have already noted the fluctuation of temperature of the interior cylinder surfaces with each stroke. With a slow motion, the cooling effect of the expansion penetrates

further into the metal of the cylinder, requiring more condensation at each admission to reheat it. The limit of rotative speed is in constructive considerations only.

Rule for Finding the Weight of Fly Wheels.

Divide the constant number 6,500,000 by the diameter of the wheel in feet and by the square of the number of revolutions per minute. The quotient will be the number of pounds per horse-power required in the *rim* of the wheel for automatic engines applied to ordinary duty. A. H. P. based upon 30 pounds, M. E. P. will be sufficient in ordinary practice for determining the total weight of fly-wheel required for a given engine. For throttling engines, a constant number of 5,000,000. will give sufficient weight for ordinary purposes. For rolling-mills and like duty, we would use a still larger constant number. The rule confines the percentage of fluctuation, or incremental variation, for all rotative speeds, within the same limits, but the fly-wheel for quite slow speeds becomes enormously heavy, as shown by the following comparison between a 4-foot stroke speeded 50 revolutions per minute, with a 16′ pulley, and a 2-foot stroke speeded 100 revolutions per minute, with a 10-foot pulley, each engine developing 100 H. P. For the 4′ stroke, $6{,}500{,}000 \div 16 \div 50^2 = 162\frac{1}{2}$ pounds in the rim per each H. P. $162\frac{1}{2} \times 100$ H. P. $= 16{,}250$ pounds total weight of rim. Cross section of rim $4\frac{1}{4}'' \times 25''$. For the 2′ stroke,

$6{,}500{,}000 \div 10 \div 100^2 = 65$ pounds in the rim for each H. P.; 65×100 H. P. $= 6{,}500$ pounds total weight of rim. Cross sections of rim, $2\frac{7}{10}'' \times 25''$. Adding for arms and hubs, the 16′ pulley will weigh at least 10 tons, while the 10′ pulley will not exceed 4 tons, and yet the effective momentum and percentage of fluctuation is the same for each.

CHAPTER II.

STANDARD AMERICAN STATIONARY BOILERS.

The Boilers now in use, and which will be used in the future for stationary purposes, are the only ones that the engineer need concern himself about, and it is to these that we now ask his attention. The present form of steam boilers may be classified as plain, flue, tubular, and water-tube or sectional boilers. The common cylinder boiler is the only representative of the first class in common use. It is perfectly cylindrical, with flat cast or wrought-iron heads. There is usually attached to this kind of boiler a "steam-drum," from which the steam-pipe leads to the engine. They are usually from 30 to 40 inches in diameter, and from 25 to 30 feet long. Where much steam is required, there are several put together side by side, and are then called a "battery," and when placed in charge of an incompetent or reckless man, a more dangerous battery was never invented—being far more dangerous than a battery of artillery. Flue boilers are generally cylindrical in form, and contain one or more flues, which pass from end to end through the interior of the boiler, beneath the water line, giving far more

heating surface than can be obtained in the plain cylinder kind. Evans' boiler (Fig. 2) shows one of this type. They are usually from 35 to 45 inches in diameter, and from 30 to 50 feet long. The whole is placed in a brick-work setting. They are used where fuel is cheap, repairs costly, and feed

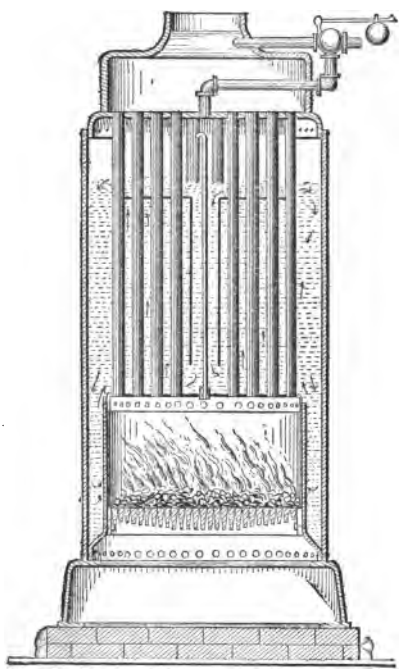


Fig. 27.

water impure, as they are easily scaled and kept clean. Like the plain cylinder boiler, they are often

placed in "batteries," and like them, are famous for battering down mills. These two classes belong to the cheap and dangerous type.

Fig. 27 shows an upright vertical fire-tube boiler. In the fire-tube boiler the gases, etc., from the furnace pass through the *inside* of the tubes, and the water is on the outside of them, while in the water-tube or sectional boiler (to be noticed directly) the reverse is the case: in them the water is inside the tubes and the fire on the outside.

Horizontal Tubular Boilers.

Fig. 28 shows a horizontal tubular steam boiler, as built by Woodbury, Booth & Pryor, Rochester, N. Y., and recommended by them to be used with their automatic cut-off engine. We give it in part, for the purpose of calling attention to what is, after all, entitled to be considered the representative stationary steam boiler in this country, and in part to call attention to some of the distinctive features adopted by the firm above mentioned, and some of the arguments used in their favor.

It will be seen that this boiler, as constructed, is not provided with a dome, in which it differs from the majority of boilers of this class, although many of the most observing engineers have of late years come to doubt the value of the dome, while the fact that they materially weaken the shell has been indisputably demonstrated.

As an argument against the utility of the dome, it

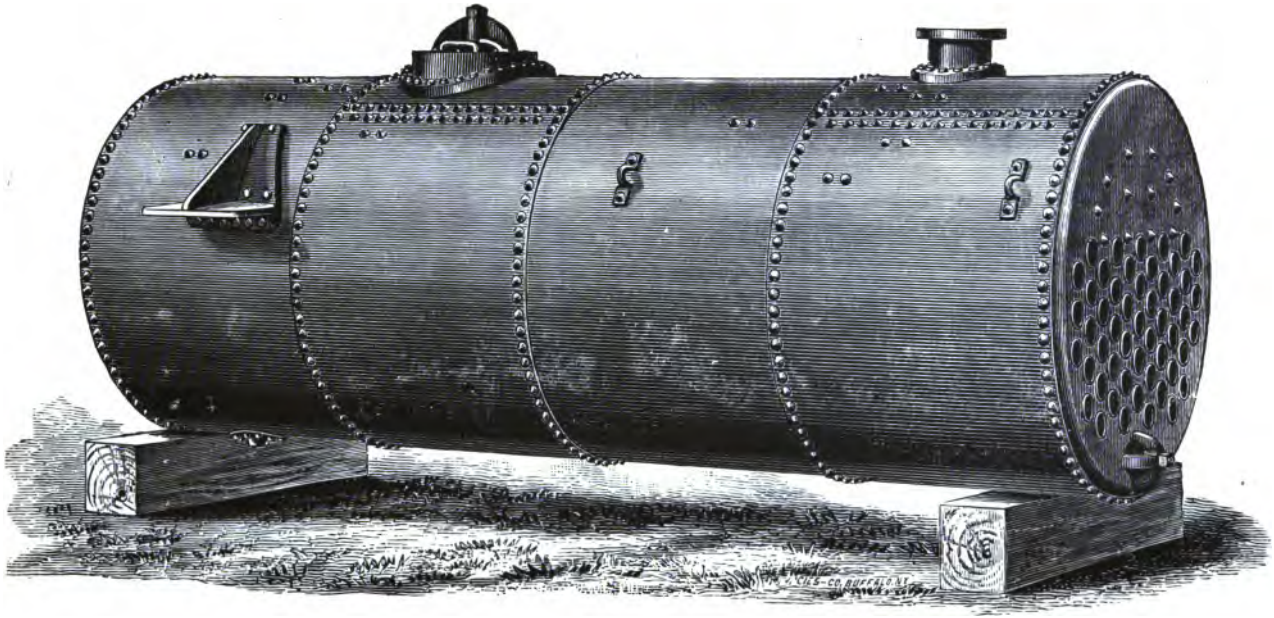


Fig. 28.—WOODBURY, BOOTH & PRYOR'S TUBULAR BOILER. Page 90.

is said that the dome, as ordinarily constructed, would contain steam enough to supply an engine from $\frac{1}{20}$ to $\frac{1}{10}$ of a minute only, and that the steam would not be of so good quality as if taken from a point nearer the great repository of heat—the water; hence, the manufacturers of this boiler construct them without domes unless specially ordered.

The perforated dry pipe, through which steam is supplied to the engine, is made of a size several times larger than the steam-pipe, and is provided at its end with a hinged valve opening inwardly to provide against the possibility of the perforations becoming stopped up.

The sheets are long enough in all cases to reach entirely around the boiler, and the quality is "Charcoal flange fire-box iron," and "Charcoal flange iron;" also the plates are planed or beveled by machines, and rivet holes are punched with a spacing machine; the object of planing or beveling the sheets before they are put together being, of course, to prevent the damage to the sheet underneath, resulting from scoring with the chisel when chipping after the sheets are riveted together. For reasons similar to this the *concave* system of riveting is used.

The accurate spacing of rivet holes by the machine insures the holes coming together fairly, and does away with the injurious practice of straining the sheets by the application of drifts.

Another point is that the tubes are so arranged as to be in rows $1'' \times 1\frac{1}{4}''$ distance apart, and well clear

of the shell of the boiler; points that have frequently been overlooked in the construction of this class of boilers, and which have sometimes tended to bring them into disrepute.

Altogether, the builders have shown an intention to popularize this simple form of boiler by attending to the detail of its construction, holding in their manufacture to the distinctive features, but changing the detail for burning tan bark, saw dust, and, in fact, any kind of fuel in use for generating steam. No better boiler of the kind is made in this country.

The present tendency in the use of steam is toward the employment of high pressures. The cause of this apparently dangerous policy on the part of engineers and engine-builders arises simply from economy. It is an axiom laid down by theory, and confirmed by practice, that the higher the boiler-pressure and the greater the ratio of expansion, the greater is the economy of fuel. Theoretically this axiom is sustained by the fact that to generate steam of the pressure of 30 pounds per square inch, about 1,190° of heat are required, while to generate steam of 120 pounds per square inch, about 1,218° of heat are required; that is to say, to produce steam of four times the boiler-pressure, less than $1\frac{28}{100}$ times the heat is required. Again, a boiler pressure of 240 pounds per square inch requires about 1,235° of heat, or $1\frac{4}{100}$ times the heat of steam at 30 pounds, and contains eight times the initial force. Practically, these dif-

ferences are so small that the same consumption of coal may be taken to evaporate the same quantity of water, whatever the pressure. Theoretically, therefore, we have only to increase our boiler-pressure to reduce our consumption of fuel. The danger arising from the use of the old style shell-boiler with very high pressures is causing them to be displaced by the sectional boilers, two makes of which we will now illustrate and describe.

Among the first boilers introduced with the view of obviating the danger arising from the use of the old-fashioned shell-boilers, is the one shown in Fig. 29. The safety which it secures, the ease with which it may be transported, erected, or removed, its economy, and the general excellence of the workmanship upon it, have caused it to be extensively adopted. As will be seen, the water is contained in tubes placed in a slanting position over the fire, and constructed of the best quality of wrought-iron.

It will also be seen that the tubes are connected by a very simple and ingenious arrangement consisting of triangular castings, forming three-way bends, and held in place by clamps and bolts. Upon the ends of each tube are screwed hollow cast-iron heads, each containing three circular recesses, in which are inserted vulcanized rubber rings, and upon these the three-way bends before mentioned are secured. In case of an accident to one of the tubes, it may be easily removed in a few minutes, and a new one inserted; or, in case an extra tube is not at hand, the

tube may be removed, and the circular openings in adjoining heads, which connect with it, closed by blanks, and the boiler continued in operation till a new tube is obtained.

The communication between the tubes is made large, so as to counteract the tendency of the steam to carry water with it and leave a tube partially empty, when a sudden demand for steam is made. The position of the steam-drum, from which the steam is taken to supply the engine, and also that of the safety-valve, are shown in the cut, which also gives an idea of the general appearance of the boiler when set.

In case an increase of boiler capacity is desired, new tubes can be added on the sides and top, and the furnace enlarged by removing only the brick work on the top and on one side. The tubes are tested before leaving the shop, up to a pressure of five hundred pounds to the square inch. The boiler may be taken to pieces for transportation, so that no part is too heavy to be carried, if necessary, in mountainous mining regions, upon the back of a mule. There is no doubt that in such a boiler a much higher pressure may be safely carried than in an old-fashioned one. Even if a tube should burst, it could cause but little

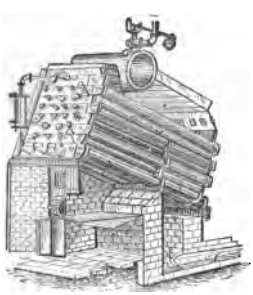


Fig. 29.

damage, and the break would immediately act as an open safety-valve for the rest of the boiler.

We are informed by the manufacturers of this boiler that in some cases, through accident or carelessness, some of the tubes have become entirely emptied of water and heated red hot, and that while in this condition they have again been pumped full of water without drawing the fire, and without any accident whatever occurring. These boilers are made by the Abendroth & Root Manufacturing Company, New York city.

DESCRIPTION OF THE BABCOCK & WILCOX WATER-TUBE BOILER.

Construction.

This boiler is composed of lap-welded wrought-iron tubes, placed in an inclined position and connected with each other, and with a horizontal steam and water drum, by vertical passages at each end, while a mud-drum connects the tubes at the rear, and lowest point in the boiler.

The end connections are in one piece for each vertical row of tubes, and are of such form that the tubes are "staggered" (or so placed that each horizontal row comes over the spaces in the previous row). The holes are accurately sized, and the tubes fixed therein by an expander. These are connected with the drum, and the mud-drum also, by short tubes expanded into bored holes, doing away with all bolts, and leaving a clear passage-way between the

several parts. The openings for cleaning opposite the end of each tube are closed by hand-hole plates, the joints of which are made in the most thorough manner by milling the surfaces to accurate metallic contact. They are tested and made tight under a hydrostatic pressure of 500 pounds per square inch

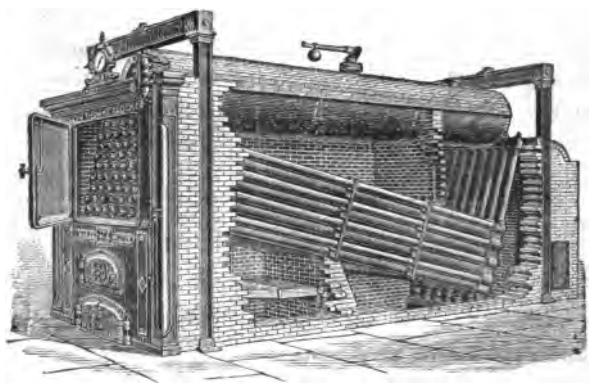


Fig. 30.

iron to iron, and without rubber packing, or other perishable substances.

Erection.

In erecting this boiler, it is suspended entirely independent of the brick-work or fire front, from wrought-iron girders resting on iron columns. This avoids any straining of the boiler from unequal expansion between it and its inclosing walls, and permits the brick-work to be repaired or removed, if necessary, without in any way disturbing the boiler. All the fixtures, such as fronts, bearers, buckstays,

gauges, valves, etc., are extra heavy and of neat designs.

Operation.

The fire is made under the front and higher end of the tubes, and the products of the combustion pass up between the tubes into a combustion chamber under the steam and water-drum; from hence they pass down between the tubes, then once more up through the spaces between the tubes, and off to the chimney.

The water inside the tubes, as it is heated, tends to rise toward the higher end, and as it is converted into steam—the mingled column of steam and water being of less specific gravity than the solid water at the back end of the boiler—rises through the vertical passages into the drum above the tubes, where the steam separates from the water, and the latter flows back to the rear and down again through the tubes in a continuous circulation. As the passages are all large and free, this circulation is very rapid, sweeping away the steam as fast as formed, and supplying its place with water; absorbing the heat of the fire to the best advantage; causing a thorough commingling of the water throughout the boiler and a consequent equal temperature, and preventing, to a great degree, the formation of deposits or incrustations upon the heating surfaces, sweeping them away and depositing them in the mud-drum, whence they are blown out.

The steam is taken out at the top of the steam-

drum, near the back end of the boiler, after it has thoroughly separated from the water.

Advantages.

The following are some of the advantages which are claimed for this boiler over those of the ordinary construction:

1.—*Thin Heating Surface in Furnace.*

The thick plates necessarily used in ordinary boilers, in the furnace, or immediately exposed to the fire, not only hinder the transmission of heat to the water, but admit of overheating, and even burning the side next the fire, with consequent strains, resulting in loss of strength, cracks, and tendency to rupture. Water tubes, however, admit of thin envelopes for the water next the fire, with such ready transmission of heat that even the fiercest fire cannot overheat or injure the surface.

2.—*Joints Removed from the Fire.*

Riveted joints with their consequent double thickness of metal, in parts exposed to the fire, give rise to serious difficulties. Being the weakest parts of the structure, they concentrate upon themselves all strains of unequal expansion, giving rise to frequent leaks, and not rarely to actual rupture. The joints between tubes and tube sheets also give much trouble when exposed to the direct fire. These difficulties are wholly overcome by the use of lap-welded water tubes, with their joints removed from the fire.

3.—*Large Draught Area.*

This, which is limited in fire tubes to the actual area of the tubes, in this boiler is the whole chamber within which the tubes are inclosed, giving ample time in the passage of the heated gases to the chimney for thorough absorption of their heat.

4.—*Complete Combustion.*

The perfection of combustion depends upon a thorough mixture of the gases evolved from the burning fuel with a proper quantity of atmospheric air; but this perfect mixture rarely occurs in ordinary furnaces, as is proven by chemical analysis, and also by the escape of smoke, upon the introduction of any smoke-producing fuel. Even when smoke is not visible, a large percentage of the combustible gases may be escaping into the chimney, in the form of carbonic oxide, or half-burnt carbon. Numerous attempts have been made to cure this evil, by admitting air to the furnace or flues, to "burn the smoke;" but though this may allow so much air to mingle with the smoke as to render it invisible, and at the same time ignite some of the lighter gases, it in reality does little to promote combustion, and the cooling effect of the air more than overbalances all the advantages resulting from the burning gas. The analysis of gases from various furnaces shows almost uniformly an excess of free oxygen, proving that sufficient air is admitted to the furnace, and that a

more thorough and perfect *mixing* is needed. Every particle of gas evolved from the fuel should have its equivalent of oxygen, and must find it while hot enough to combine, in order to be effective. In this boiler the current of gases, after leaving the furnace, are broken up and thoroughly mingled by passing between the staggered tubes, and have an opportunity to complete their combustion in the triangular chamber between the tubes and drum.

That this does really take place is proved by an analysis by Dr. Behr of the escaping gases from a stack of these boilers at Matthiessen & Weicher's sugar-refinery. He made many separate analyses at different times, and in no case was there more than a trace of carbonic oxide, even when there was less than one per cent. of uncombined oxygen.

5.—*Thorough Absorption of the Heat.*

There are important advantages gained in this respect in consequence of the course of the gases being more nearly vertical to the heating surface, impinging thereon instead of gliding by in parallel lines as in fire-tube boilers. The currents passing three times across and between the staggered tubes are brought intimately in contact with all parts of the heating surface, rendering it much more efficient than the same area in ordinary tubular boilers.

The experiments of Dr. Alban and of the U. S. Navy have proved that a given surface arranged in

that manner is 30 per cent. more efficacious than when in the form of fire tubes as usually employed.

6.—*Efficient Circulation of Water.*

As all the water in the boiler tends to circulate in one direction, there are no interfering currents; the steam is carried quickly to the surface, all parts of the boiler are kept at a nearly equal temperature, preventing unequal strains, and by the rapid sweeping current the tendency to deposit sediment on the heating surface is materially lessened.

7.—*Quick Steaming.*

The water being divided into many small streams, in thin envelopes, passing through the hottest part of the furnace, steam may be rapidly raised in starting, and sudden demands upon the boiler may be met by a quickly increased efficiency.

8.—*Dryness of Steam.*

The large disengaging surface of the water in the drum, together with the fact that the steam is delivered at one end and taken out at the other, secures a thorough separation of the steam from the water, even when the boiler is forced to its utmost. Many boilers make wet steam, "priming" or "foaming," as it is called, and in many "superheating surface" is provided to dry the steam thus formed; but such surface is always a source of trouble, and is incapable of being graduated to the varying requirements of

the steam. Hence a boiler which makes dry steam is to be preferred to one that dries steam which has been made wet.

9.—*Steadiness of Water Level.*

The large area of surface at the water line, and the ample passages for circulation secure a steadiness of water level not surpassed by any boiler.

10.—*Freedom for Expansion.*

The triangular arrangement of the parts forming a flexible structure allows any member to expand without straining any other, the expanded connections being also amply elastic to meet all necessities of this kind. This is of great importance, because the weakening effect of these strains of unequal expansion between rigidly connected parts is a prolific cause of explosions in ordinary boilers. The rapid circulation of the water, however, in this boiler, by keeping all parts at the same temperature, prevents to a large extent unequal expansion.

11.—*Safety from Explosions.*

The freedom from unequal expansion avoids the most frequent cause of explosions, while the division of the water into small masses prevents serious destructive effects in case of accidental rupture. The comparatively small diameter of the parts secures, even with thinness of surface, great excess of strength over any pressure which it is desirable to use. So

powerful is the circulation of the water, that no part will be uncovered to the fire until the quantity of water in the boiler is so far reduced that if overheating should occur no explosion could result.

12.—*Durability.*

Besides the important increase of durability due to the absence of deteriorating strains, and of thick plates and joints in the fire, there is no portion of the boiler exposed to the abrasive action which so rapidly destroys the ends of fire tubes, or the blow-pipe action of the flame upon the crown sheet, bridge walls, and tube sheets, and which is so destructive frequently to ordinary, particularly locomotive boilers. Neither is there any portion of the surface above the water level exposed to the fire.

13.—*Least Loss of Effect from Dust.*

The ordinary fire tube, or flue, receiving the dust from the fire on the interior, is quickly covered from one-third to one-half its surface, and in time is completely filled. The water-tube, however, will retain but a limited quantity on its upper side, after which it becomes in a measure self-cleaning.

14.—*Accessibility for Cleaning.*

This is of the greatest importance, and is secured to the fullest extent. Hand holes, with metal joints, opposite each end of each tube, permit access thereto for cleaning, and a manhole in the steam and water

drum, and bonnet in mud drum, are provided for the same purpose. All portions of both the exterior and interior surface are fully accessible for cleaning. The occasional use of steam through a blowing pipe attached to a rubber hose operated through doors in the side walls, will keep the tubes free from soot and in condition to receive the heat to the best advantage.

15.—*Ease of Transportation.*

Being made in sections, which are readily put together with a simple expanding tool, these boilers may be easily and cheaply transported where it would be wholly impossible to place a boiler of ordinary construction. They can be made in parts small enough for mule transportation, if required.

16.—*Repairs.*

As now constructed these boilers seldom require repairs, but should, from any cause, such be necessary, any good mechanic can make them with the tools usually found in boiler shops. Should a tube require to be renewed, it can be removed, and a new one substituted the same as in a tubular boiler.

17.—*Capacity.*

This is a point of the greatest importance, and upon it depends, in a large measure, the satisfactory performance of any boiler in several particulars. Unless sufficient steam and water capacity is provided, there will not be regularity of action; the

steam pressure will suddenly rise and as suddenly fall, and the water level will be subject to frequent and rapid changes; and if the steam is drawn suddenly from the boiler, or the boiler crowded, wet steam will result.

The proportions of this boiler have been adopted after numerous experiments with boilers of varying capacity; and experience has established that this boiler can be driven to the utmost, carrying a steady water level and steam pressure, and always furnishing dry steam.

The cubical capacity of this boiler, per horse-power, is equal to that of the best practice in tubular boilers of the ordinary construction. The fire surface being of the most effective character, these boilers will, with good fuel and a reasonably economical engine, greatly exceed their rated power, though it is seldom economy to work a boiler above its nominal power. The space occupied by the boiler and setting is equal to about two-thirds that of the same power in tubular boilers.

The Pond & Bradford Sectional Boiler.

Fig. 31. A represents a steam drum, which is made of the best brand of iron, 24″ in diameter, and $\frac{5}{16}$″ in thickness, while the length is governed by the number of sections of tubes required to be attached to it. This drum has two double riveted longitudinal seams on the sides where they are not exposed to the fire. The heads are made of wrought-

iron, well-stayed. A man-hole is placed in one end, by means of which all the parts are easily accessible. The sections are attached by means of well-riveted joints to the bottom of the drum. The different sections are made after the following manner: malleable iron or steel spherical-shaped sections, or connecting spheres, are attached to each other by wrought-iron tubes, 3″ in diameter, fitted into holes bored to fit the tube, which is then inserted, and expanded with a suitable tool, thereby making a thoroughly tight and secure joint.

Within each of the 3″ tubes are placed others of the same material, 1½″ in diameter, and fitted and expanded in the same manner, but with this difference: the 3″ tubes are attached to the side of the spheres, while the 1½″ tubes pass directly through, and are fitted to the opposite side. By this arrangement it will be understood that the water is contained between the outside and inside tubes, while the 1½″ tubes are open at the ends. The heat passing inside the 1½″ tubes, and outside of the 3″ tubes, greatly increases the heating surface. Thus it is claimed by the inventors to generate steam rapidly, and with the smallest amount of fuel. In the centre of all these tubes is placed a large tube of 5″ diameter, which contains water, and, in practice, the water rises in all the 3″ tubes, and descends through the 5″ centre tube, thus insuring a good circulation, which is a very essential point in steam boilers. The bottom of each section is provided with an opening, which is covered

by a plate. By removing these plates, the bottom of each section can be readily washed and inspected. The flanges to which these plates are attached, also those on top of the sections, are drilled to the same template, thereby allowing the sections to be reversed when the lower part becomes corroded or wasted by the action of the fire. Each of the joints on the sections are faced and put together with asbestos

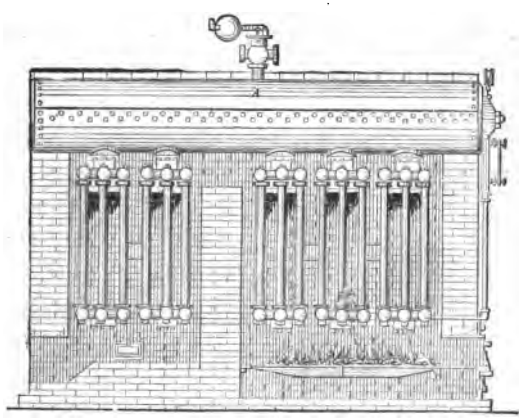


Fig. 31.

packing, upon which the fire has no effect. Two bars of square iron are placed across through each section, thereby making it possible to remove any section for inspection repairs without disturbing any of the others. The bottom of each section is connected with the pipe, which is of sufficient capacity to insure a uniform water level.

The pipes are large, and, as represented, are con-

nected with the lowest and highest points in the boiler, thereby avoiding the difficulties which appear with some other arrangements. The hot air and gases rise from the fire between the wall and bridge wall, and coming in contact with the steam drum pass along through an opening into the combustion chamber between the walls, where in their downward course the gases and smoke are claimed to be nearly, if not perfectly, consumed. The passage leads to the chimney. There should always be a damper in this passage, so as to retain the heat, to insure the most perfect economy, as great losses occur continually by allowing the heat to pass off at too high a temperature. The water may be carried as high as may be desired, but it is thought best to carry it as represented in the cut, and take the steam from the center of the steam drum so as to draw on all parts of the boiler equally.

Bates's Patent Steam Generator.

The following description is taken substantially from the specifications of the patent, which was granted September 10, 1878. *A* is the main cylindrical body of the boiler, from end to end of which extend a series of tubes, *a*. On the under side, at the rear end of the body, is the leg, *A'*, of the same width as and communicating with the main body, the same leg being semi-cylindrical at the bottom, and the opposite flat sides, *b*, *b'*, being strengthened with suitable transverse stays passing between the

series of tubes, *d*, which extend from front to back of the leg.

The main body, *A*, of the boiler is situated directly above the furnace, which has the usual grate bars, *D;* ash-pit, *E;* and bridge, *G;* so that the lower portion of the main body, *A*, is exposed to the products of combustion as they pass toward and over the bridge into the flue, *H*, at the rear of the same.

The direct course of the products of combustion is abruptly interrupted by the leg, *A'*, the main

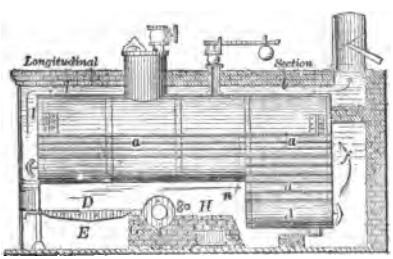


Fig. 32.

portion of which is below the level of the bridge, and hence the leg is subjected to greater heat than any other part of the boiler.

The products of combustion, after passing through the tubes of the leg, and through and between the front, side and back walls, return through tubes, *a*, in the body of the boiler to the front of the same, whence they are conducted through flues, *i*, *i*, to the chimney.

It has been found in practice that by this arrange-

ment of the leg, *A'*, and its tubes at the rear of the boiler, and by its location in the flue at the rear of and below the top of the bridge, so that the leg shall be the hottest part of the boiler, two important results are obtained—viz., the rapid generation of steam and the constant and free circulation of water in the boiler.

Steam-boilers have previously been so constructed that the products of combustion shall pass first through one set of tubes in a lower part of the boiler, and return through another set of tubes in upper part of the same; but steam-boilers of this class have heretofore been self-contained—that is, with water-spaces at the sides of the fire-place, and with shells of such a character at the rear (where the lowest set of tubes occurs) as to demand an expensive system of stays, whereas the shell of this improved boiler consists of simply a long cylinder, united by flat sides to a short leg having a semi-cylindrical base, and can be much more economically constructed than ordinary boilers of the class to which it relates.

A water-heater, *J*, is built in, and, in fact, forms the upper part of the bridge, *G;* the water being introduced into this heater through a pipe, *M*, which extends nearly to one end of the heater, and is conveyed from the latter through two pipes, *NN'*, near the opposite end, the said pipes communicating with the leg, *A'*, of the boiler; so that a constant circulation of water through the heater, *J*, is insured.

The heater consists of a vessel made of steel

plates, and is preferably of cylindrical form. Steel is calculated to effectually resist the intense heat to which the heater must be subjected, and which would rapidly destroy a heater made of wrought-iron plates.

It has been found that by forcing the heated water into the leg of the boiler the accumulation of sediment in the body, *A*, of the boiler is prevented, owing to the fact that the heat of the water in the leg, *A'*, causes the deposit of the impurities as soon as the feed-water enters the boiler, the sediment being thus caused to accumulate on the bottom of the leg, *A'*, where it is below the line of great heat, and consequently does not tend to hasten the burning out of the boiler-plates.

The gas-burner, which is shown to the right and below the steel feed-water heater, was patented June 13, 1876, by Mr. Bates. Its object is to produce complete and effectual combustion. By this appliance fresh air is injected, and this heated to a very high temperature before it mingles with and ignites the gases.

The idea was first suggested to Mr. B. nearly sixteen years ago, and, after some experiments, he made application for a patent for heating and supplying fresh hot air to mingle with the gases as it passes over the bridge-wall. The gases there ignite, and the flame is carried under the boiler and through the lower set of tubes, and around the vertical sides where there is 4″ space. As arranged under this

patent duplex steam generator it is claimed to make a perfect combustion.

The grate-bar herewith shown was patented by Mr. Bates, June 13, 1876. It is a lock-bar giving a free circulation of air throughout the grate.

In a test made by Mr. John Cherry, engineer at Schofield's Mills, Manayunk, with a 60-inch Bates Steam Generator, time ten hours, with feed-water entering the boiler at about 140°, 10.518 pounds of water was evaporated by every pound of coal.

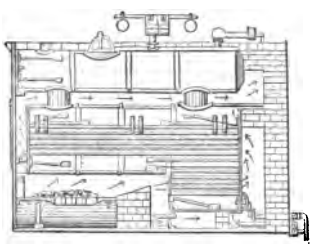


Fig. 33.

In order, however, to reduce the loss of heat to the smallest amount possible, Mr. Bates has added the steam drum shown in Fig. 33, besides minor alterations in bridge-wall and other parts, which can be best understood by comparison of the two Figs., 32 and 33.

Requirements of a Perfect Steam Boiler.

1st. It should be simple in construction, and be made of the best materials sanctioned by use.

2d. It should have a constant and thorough circulation of water throughout the boiler, so as to maintain all parts at one temperature.

3d. It should be provided with a mud-drum to receive all impurities deposited from the water in a place removed from the action of the fire.

4th. It should be provided with a combustion-chamber, so arranged that the combustion of the gases commenced in the furnace may be completed before the escape to the chimney.

5th. All parts should be readily accessible for cleaning and repairs. This is a point of the greatest importance as regards safety and economy, and has heretofore been possessed only by plain cylinder and large flue boilers.

6th. The heating surface should be arranged as nearly as possible at right angles to the currents of heated gases, and so break up the currents as to extract the entire available heat therefrom.

7th. The boiler should have a large water surface for the disengagement of the steam from the water in order to prevent foaming.

8th. It should have large and free passages between the different sections to equalize the water line and pressure in all.

9th. It should have a steam and water capacity sufficient to prevent sudden fluctuation in pressure or water level.

10th. It should have, if possible, no joints exposed to the direct action of the fire.

11th. It should have a great excess of strength over any legitimate strain, and should be so constructed as not to be liable to be strained by unequal expansion.

12th. It should be durable in construction, and not liable to require early repairs.

13th. The water space should be divided into sections, and so arranged that should any section give out, no general explosion can occur, and the destructive effects will be confined to the simple escape of the contents.

14th. It should be proportioned for the work to be done, and be capable of working to its full rated capacity with the highest economy.

15th. It should be provided with the very best gauges, safety valves, and other fixtures.

Horse-power of Boilers.

Strictly speaking, there is no such thing as "horse-power" to a steam boiler; it is a measure only applicable to dynamic effect. But as boilers are necessary to drive steam-engines, the same measure applied to steam-engines has come to be universally applied to the boiler, and cannot well be discarded. In consequence, however, of the different quantities of steam necessary to produce a horse-power with different engines, there has been great need of an accepted standard by which the amount of boiler required to provide steam for a commercial horse-power may be determined.

This standard, as fixed by Watt, was one cubic foot of water evaporated per hour from 212° for each horse-power. This was, at that time, the requirement of the best engine in use. At the present time, Prof. Thurston estimates that the water required per hour, per horse-power, in good engines is

equal to the constant 200, divided by the square root of the pressure, and that in the best engines this constant is as low as 150. This would give for good engines, working with 64 lbs. pressure, 25 lbs. water, and for the best engines, working with 100 lbs., only 15 lbs. water per hourly horse-power.

The standard, therefore, adopted by the judges at the late Centennial Exhibition, of 30 lbs. water per hour, evaporated from 212°, for each horse-power, is a fair one for both boilers and engines, and has been favorably received by engineers and steam users; but as the same boiler may be made to do more or less work with less or greater economy, it should also be required that the rating of a boiler be based on the amount of water it will evaporate at its most economical rate.

A fault frequently met with in steam boilers is the carrying over of water mechanically mixed with the steam, which water not only carries away heat without any useful effect, but, when present in any marked quantity, itself becomes a source of danger and of serious loss in the engine. Many boilers show a high apparent evaporation in consequence of furnishing "wet steam," while practically they are anything but economical. Parties have been known to claim an evaporation of 19 to 20 pounds per pound of coal, where the highest practically possible is not over 13. Such boilers are dear at any price.

The cause of priming may be either impure water,

too much water, or improper proportions in the boiler. When a boiler is found to form wet steam with good water, carried at a proper height, it is a proof of wrong design.

The amount of priming in different boilers varies greatly, and as yet there is not sufficient data to establish any definite ratio for boilers in ordinary use. The experiments of M. Hirn, at Mulhouse, showed an average of at least 5 per cent.; Zeuner sets it down as approximately from 7½ to 15 per cent., while the careful experiments at the American Institute in 1871 show in cylindrical tubulars 7.9 per cent.

Efficiency of the Furnace.

A steam generator is composed of two distinct parts, each with its independent function. The furnace is for the proper combustion of the fuel, and its duty is performed to perfection when the greatest amount of heat is obtained from the given weight of combustible. The boiler proper is for the transfer of the heat thus generated into useful effect by evaporating water into steam, and its function is fulfilled completely when the greatest possible quantity of heat is thus utilized. To a lack of appreciation of this fact, and of a knowledge of the principles involved, are chargeable much waste of money and disappointment, both to inventors and steam users.

Combustion.

Combustion may be defined as "the union of two dissimilar substances, evolving light and heat." In

ordinary practice, one of these is always the oxygen in the atmosphere, and the other is the fuel employed. Every pound of fuel requires a given quantity of oxygen for its complete combustion, and thus a given quantity of air. This varies with different fuels, but in every case less air prevents complete combustion, and an excess of air causes waste of heat to the amount required to heat it to the temperature of the escaping gas.

Prof. Schwackhoffer, of Vienna, found in the boilers used in Europe an average excess of 70 per cent. of the total amount passing through the fire —or that over three times the theoretical amount was used.

A series of analyses by Dr. Behr of the escaping gases from a Babcock & Wilcox boiler, with chimney draft, showed an average excess of air equal to 48 per cent. of the whole quantity.

A series of 12 tests made by the same with artificial blast, gave an average excess of only 22 per cent. of the whole quantity, and in a few cases none at all, with only traces of carbonic oxide, showing perfect combustion.

In a summary of experiments made in England, published in Bourne's late large work, "Steam, Air and Gas Engines," it is stated that:

"A moderately thick and hot fire, with rapid draft, uniformly gave the best results.

"Combustion of black smoke by additional air was a loss.

"In all experiments the highest result was always obtained when all the air was introduced through the fire bars.

"Difference in mode of firing only, may produce a difference of 13 per cent." in economy.

Boiler Efficiency.

As a boiler is for making steam, it can only utilize for that purpose heat of a greater intensity or higher temperature than the steam itself, therefore the gases of combustion cannot be reduced below that temperature, and the heat thereby represented is lost. The amount of this loss will depend upon the amount of air admitted to the furnace, and the increase of temperature at which it escapes. The more air admitted the greater the loss; hence the fallacy of all those schemes which admit air above the fire.

The rate of combustion should not exceed 0.3 pound of coal per hour per square foot of heating surface, except where *quantity* of steam is of greater importance than economy of fuel. Where a blast is used, the grate surface should be proportionately reduced to secure the best economy.

"The maximum conductivity or flow of heat is secured by so designing the boiler as to secure rapid, steady, and complete circulation of the water within it . . . . and securing opposite directions of flow for the gases on the one side and the water on the other."*

* Prof. R. H. Thurston.

The accumulation of scale on the interior, and of soot on the exterior, will seriously affect the efficiency and economy of the boiler. Only one-eighth of an inch deposit of soot renders the heating surface practically useless. Only one-sixteenth of an inch of scale or sediment will cause a loss of 13 per cent. in fuel. The result of a bad setting for a boiler has been known to be a loss of 21 per cent. in economy.

Fuel.

The value of any fuel is measured by the number of heat units which its combustion will generate. A unit of heat is the amount required to heat one pound of water one degree Fahrenheit. The fuel used in generating steam is composed of carbon and hydrogen, and ash, with sometimes small quantities of other substances not materially affecting its value.

"Combustible" is that portion which will burn, the ash or residue varying from 2 to 36 per cent. in different fuels.

The effective value of all kinds of wood per pound, when dry, is substantially the same.

"Slack," or the screenings from coal, when properly mixed—anthracite and bituminous—and burned by means of a blower on a grate adapted to it, is nearly equal in value of combustible to coal, but its percentage of refuse is greater.

A number of firms are using slack with decided economy, under Babcock & Wilcox boilers, in which there is ample space below the tubes for the dust to

accumulate without covering heating surface or impairing the draft.

Incrustation and Scale.

Nearly all waters contain foreign substances in greater or less degree, and though this may be a small amount in each gallon, it becomes of importance where large quantities are evaporated. For instance, a 100 H. P. boiler evaporates 30,000 lbs. water in ten hours, or 390 *tons* per month; in a comparatively pure water there would be 88 pounds of solid matter in that quantity, and in many kinds of spring water as much as 2,000 lbs.

The nature and hardness of the scale formed of this matter will depend upon the kind of substances held in solution and suspension. Analyses of a great variety of incrustations show that carbonate and sulphate of lime form the larger part of all ordinary scale, that from carbonate being soft and granular, and that from sulphate hard and crystalline. Organic substances in connection with carbonate of lime will also make a hard and troublesome scale.

The presence of scale or sediment in a boiler results in loss of fuel, burning and cracking of the boiler, predisposes to explosion, and leads to extensive repairs. It is estimated that the presence of $\frac{1}{16}$ inch of scale causes a loss of 13 per cent. of fuel, $\frac{1}{4}$ inch 38 per cent., and $\frac{1}{2}$ inch 60 per cent. The Railway Master Mechanics' Association of the United States estimates that the loss of fuel, extra repairs,

etc., due to incrustation, amount to an average of $750 per annum for every locomotive in the Middle and Western States, and it must be nearly the same for the same power in stationary boilers.

Means of Prevention.

It is absolutely essential to the successful use of any boiler, except in pure water, that it be accessible for the removal of scale; for though a rapid circulation of water will delay the deposit, and certain chemicals introduced into the water will lessen it, yet the only certain cure is periodical inspection and mechanical cleaning. This may, however, be rendered less frequently necessary, and the use of very bad water more practical, by the use of some preventives. The following are a fair sample of those in use, with their results:

Waters containing bicarbonate of lime in solution may be caused to deposit a considerable portion of the same by simply heating to 212°, which drives off a portion of carbonic acid, and reduces the bicarbonate to the insoluble carbonate. This principle is the basis of a large number of heaters and "lime-catchers," but it has no effect on other impurities.

The addition of milk of lime or of metallic zinc has a similar effect, and they have been used with success in waters charged with bicarbonate of lime; but on sulphate of lime they have no action.

Oak, hemlock, and other barks and woods, sumac, catechu, logwood, etc., are effective in waters con-

taining carbonates of lime or magnesia, by reason of their tannic acid, but are injurious to the iron, and not to be recommended.

Molasses, cane-juice, vinegar, fruits, distillery slops, etc., have been used with success so far as scale is concerned, by reason of the acetic acid which they contain; but this is even more injurious to the iron than tannic acid, while the organic matter forms a scale with sulphate of lime when it is present.

All "anti-incrustators" containing organic matter are to be avoided. M. Bidard's observations show that they help rather than hinder incrustations.

Barium chloride and milk of lime are used with good effect at Krupp's Works, in Prussia, for waters impregnated with gypsum.

Soda ash and other alkalies are very useful in waters containing sulphate of lime, by converting it into a carbonate, and so forming a soft scale, easily cleaned. But when used in excess they cause foaming, particularly where there is oil coming from the engine, with which they form soap. All soapy substances are objectionable for the same reason.

Petroleum has been much used in late years. It acts best in waters in which sulphate of lime predominates. As crude petroleum, however, sometimes helps in forming a very injurious crust, the refined only should be used.

Rogers' tannate of soda is probably the best preparation for general use, but in waters containing

much sulphate it should be supplemented by a portion of carbonate of soda.

For muddy water, particularly if it contains salts of lime, no preventive of incrustation will prevail except filtration, and in almost every instance the use of a filter, either alone or in connection with some means of precipitating the solid matter from solution, will be found very desirable.

In all cases where impure or hard waters are used, frequent "blowing" from the mud-drum is necessary to carry off the accumulated matter, which if allowed to remain would form scale.

Covering Steam Pipes, etc.

The loss by radiation from unclothed pipes and vessels containing steam is considerable, and in the case of pipes leading to steam-engines, is magnified by the action of the condensed water in the cylinder. It, therefore, is important that such pipes should be well protected.

There is a wide difference in the value of different substances for protection from radiation, their value varying nearly in the inverse ratio of their conducting power for heat, up to their ability to transmit as much heat as they will radiate, when they become detrimental, rather than useful, as covering.

Hair or wool felt has the disadvantage of becoming soon charred from the heat of steam at high pressure, and sometimes of taking fire therefrom. This has led to a variety of "cements" for covering pipes—

composed generally of clay mixed with different substances, as asbestos, paper fibre, charcoal, etc. A series of careful experiments made at the Massachusetts Institute of Technology, in 1871, showed the condensation of steam in a pipe covered by one of them, as compared with a naked pipe, and one clothed with hair felt, was 100 for the naked pipe, 67 for the "cement" covering, and 27 for the hair felt.

A smooth or polished surface is of itself a good protection—polished tin or Russia iron having a ratio for radiation of 53 to 100 for cast iron. Mere color makes little difference. "Mineral wool," a fibrous material made from blast furnace slag, is a good protection, and is incombustible; its exact conducting power is not known, but it is believed to be not much inferior to wool.

The writer's own experience is not favorable to any of the so-called clay, paper-pulp, or cement feltings; but he can conscientiously recommend the combination hair and asbestos felting of the H. W. Johns Manufacturing Company, of New York City, as one of the best, if not the best, article for steam boilers yet brought out, and he is confident that his brother engineers will agree with him after a trial of this make of covering.

Abuse of Steam Boilers.

It would be difficult to assign any reasonable cause for this neglect, except that it may arise from the fact

that nearly the whole attention of the engine builders has been concentrated on the improvement and perfection of the steam *engine*, and the engineer, following the example of the constructors, generally neglects his boiler, and devotes all his time and care to his engine.

One of the most common, and at the same time greatest, abuses of the boiler is the reckless practice of blowing out the water as soon as the fires are hauled, and the boiler still hot. Under such circumstances the contraction of the crown-sheet, tube-sheets and tubes is so unequal and rapid that it results in the end in the ruin of the boiler. Boilers well made, of good material and design, have been ruined by blowing them out under a heavy pressure of steam, and then immediately filling them with cold water. After the fire has been hauled, the connection doors and furnace door should be opened, and the boiler be permitted to cool off before the water is blown out, which should be done under a pressure of not more than 10 pounds—the less the better—otherwise leaky seams and tubes, or fractured stays or braces, will be the result. Some engineers seem to think that mud and other deposit can be *blown out* by a heavy pressure of steam; but this is an error, as all the older members of the profession well know. Another abuse is the pumping of cold water (sometimes ice-cold water in winter time) into the boiler with the donkey pump. Now, unless you can pump hot water from the heater with the donkey pump, it should be

used sparingly, and that only when the boiler cannot be pumped up by any other means. As a general thing, boilers leak most at that point where the cold water from the donkey pump impinges upon the metal.

Another abuse is that boilers are not cleaned out often enough, but the scale-deposits are allowed to accumulate on the crown-sheet, tubes and flues, until it becomes so hard and thick that the water cannot protect the iron, and it is burnt and destroyed.

In all cases when boilers are laid up or out of use they should be opened, cleaned out, and examined to see if the stays or braces are broken, loose, or much worn. At the same time the hammer-test should be applied to all accessible parts. All oxidation should be removed, and such places painted with good red lead or "poco" paint.

Testing Boilers.

There are two methods in general use, known as the "hydraulic-test" and "hammer-test." The former test consists in filling the boiler with water and then with a hand force-pump raising the pressure up to that which it is supposed the boiler will stand, then allowing $\frac{2}{3}$ of the water-pressure for the steam-pressure. For instance, if a boiler stands a pressure of 90 pounds per square inch water-pressure, 60 pounds would be the steam-pressure. The $\frac{2}{3}$ rule is that in use by the U. S. Local Inspectors. The "hammer-test" is applied to all accessible parts of

the boiler, such as the shell, crown-sheet, flues, front and back connections, tube-sheets and braces, by tapping with a light hammer. The experienced engineer can easily tell from the sound produced whether the part struck is sound or not.

As regards these tests, some engineers prefer one, some the other, but in my opinion whenever a steam boiler is tested, *both* the hydraulic and hammer-test should be applied. But whether one or both, the testing of boilers requires the greatest care and skill, and should never be applied to any boiler unless all the conditions are understood, such as general condition, age, etc., and never except by persons who fully understand the object and effect of the test. The steam gauge used during the test should be a standard one, and one *known to be correct* by the person testing the boiler, beyond all doubt. It stands to reason that if the gauge be not correct the test is useless; and besides, you run the risk of injuring the boiler by an excess of pressure.

Explosion of Steam Boilers.

The one great cause of boiler explosion is the inability of the boiler to withstand the pressure to which it is subjected at the time; and this may be brought about by any one of the following causes, viz.:

1. Bad design, in which the boiler may not be properly strengthened by stays and braces; deficient water-space, preventing the proper circulation of the water.

2. Bad workmanship, caused by the punching and riveting being done by ignorant and unskilled men.

3. Bad material, caused by blisters, lamination, and the adhesion of sand or cinders in the rolling of the plate.

4. By excessive pressure, caused by the gross carelessness or recklessness of the engineer, or by defective steam-gauges, or inoperative safety-valves, they being over-weighted, jammed, or otherwise out of order.

5. Overheating of the plates, caused by shortness of water, which in turn is caused by the carelessness or ignorance of the engineer, in allowing the water to get low, and then putting on the pump, after the plates have become overheated.

6. By accumulation of scale, mud, or other deposit, which prevents the water gaining access to the iron. This causes the seams to leak, the crown-sheet to bulge or come down; and when this happens the boiler is in a dangerous condition, and liable to explode.

All steam boiler explosions are caused by one or more of the above causes. Were all boilers of good design, material and workmanship, and in charge of none but sober, intelligent and experienced engineers, such a thing as a boiler explosion would be almost unknown.

NOTE.—The Author is indebted to The Babcock & Wilcox Co., New York, for the valuable information contained on pages 112 to 128.

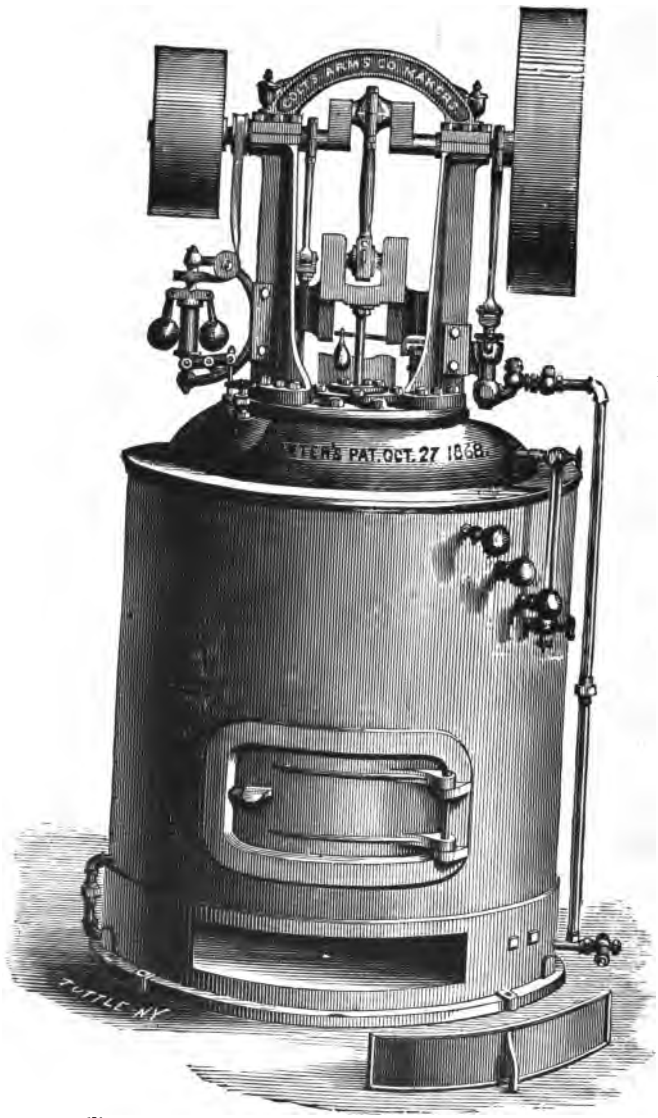


Fig. 34.—The Baxter Steam-Engine. Page 129.

CHAPTER III.

STANDARD AMERICAN PORTABLE STEAM-ENGINES AND BOILERS.

MANUFACTURERS and others requiring small steam-power, who have not the requisite space available for boiler-room, want a steam-engine which, with its boiler, is of small dimensions, and yet will develop sufficient power.

Numerous machines have been invented to supply this want. Fig. 34 shows the Baxter steam-engine, which has a world-wide reputation.

The fact that the furnace, engine, boiler, governor, pump, gauge-cocks, safety-valve, steam-gauge, and water-bottom (which is also a heater and mud-drum), composing a 10 horse-power machine, can be set up on a floor space of 4½ feet, and yet be only 9 feet in height, is hardly credible until one comes to examine the admirable arrangement of the different portions.

The compactness of this machine renders it easily transportable, and its comparatively light weight (ranging from 1280 pounds in the 2 horse-power to 4300 in the 10 horse-power) allows it to be placed directly in the story or room in which its work is required.

The boiler of the Baxter engine (Fig. 34) is tubular, but is in no way the same as the ordinary vertical tubular boiler. Placed over the fire is a large combustion-chamber, which curves in for a short distance at the bottom. From this curvature flues descend all around the circumference of the boiler, the water to be heated being situated over this chamber and around the flues. The products of combustion arising from the fire come first in contact with the upper part of the chamber, above which is the greatest quantity of water, and then, descending through the short flues, strike the water-bottom, whence they ascend on the outside of the boiler, between it and the sheet-iron jacket with which it is covered, and pass off at the chimney-flue.

In the combustion chamber all the gas and smoke is consumed, and the heat, together with that radiated from the fire-grate, by passing over the water-bottom, warms the water before it enters the boiler. So thoroughly does this method take up and utilize the caloric, that the hand may be with impunity placed on the pipe leading from the engine to the chimney-flue.

Attached to the boiler is a pump, which forces the feed-water into the water-bottom, from which it passes into the boiler by a connecting-pipe on the opposite side from its entrance. Referring to Fig. 34, the pump is shown above, at the right-hand side, immediately under the large wheel, the water passing into the water-bottom beneath the boiler, at the lower

end of the vertical tube. The small portion of pipe visible at the left-hand side serves to lead the water into the boiler.

The cylinder is situated directly in the steam-dome, thus effectually preventing any condensation of steam, so that the latter is always used dry, and a greater power obtained. By this arrangement, the cylinder head is at once the bed-plate of the engine and the cover of the boiler. The cylinder-valve is placed on the upper left-hand side of the boiler, and its arrangement can be seen from the figure. The water-bottom being used as a mud-drum, all sediment and impurities can be readily blown out at the opening at which the feed-water empties, thus keeping the interior of the boiler free from deposit and dirt. By means of a plug of brass, made hollow and filled with lead, which is inserted in the crown-sheet, all danger of explosion from low water is obviated; for the moment the water falls below the level of the upper part of the crown-sheet, the lead, being melted, drops out, and permits the escape of the steam.

The advantages offered by this engine, besides those of its occupying small space, are its economy of fuel and great facility of management and repair.

It is claimed that it consumes less fuel, in a given time, than any small engine of equal power extant. Half a bushel of anthracite coal a day is sufficient to run a 3 horse-power engine at 266 revolutions per minute, and a ton of coal per month is rarely ex-

ceeded. When wood is used, about a quarter of a cord per day is all that is required.

The whole machine takes up no more space than a good-sized stove, and a boy can run it with very little teaching. It is made at the factory of Colt's Patent Fire-arms Manufacturing Company, Hartford, Conn. If any portion become broken or lost, it can be instantly replaced with another exactly similar, as every part is made with special tools, on the same principle as the Waltham watches, or Colt's rifles and pistols.

Fig. 35 shows the style of portable engine made by the Watertown (N. Y.) Steam-Engine Company. The engine frame is very heavy and substantial, with liberal openings at the sides to admit of free access to all the working parts within. The guides and pillow-block are cast with the frame, so that they cannot become loose or out of line. All wearing surfaces are large and easily accessible. Ample provision is made for taking up any wear of the guides or boxes. Oil-cups are placed upon all bearings.

The connecting-rod boxes are of the best bronze, with straps, gibs and keys accurately milled. All bolts, nuts and set screws are of standard size and thread. Stud bolts are used to hold on the cylinder head and steam-chest cover, permitting their removal without loosening and wearing the thread of the bolt.

The cylinder is jacketed to prevent loss of heat. Drips are placed in the cylinder and steam-chest to carry off the water of condensation.

The crank is made in disc form and balanced, permitting the engine to run at high speed without jarring.

Fig. 35.

The governor is extremely sensitive, and holds the engine under such perfect control that the main belt

may be thrown off while the engine is running without increasing the speed.

The piston is ring and spring; the piston-rod is screwed into the cross-head and secured by a jam nut. It can thus be adjusted to meet the wear of the connecting-rod without the use of packing in the boxes. The pump is driven from the cross-head; it is very simple and reliable; either valve can be removed without disturbing the other, and the whole pump is readily taken apart for cleaning and repairs. The engine is supplied with a heater, by which the heat of the exhaust steam is imparted to the feed-water. The heater is easily accessible for repairs. After heating the water, the exhaust steam is carried into the smoke-pipe, killing the sparks and increasing the draft.

The boiler is built throughout of the best material, and is carefully made and thoroughly tested. The base-plate, which holds the boiler and engine, contains the ash-pit, with door for cleaning and damper for regulating the draft. A full set of foundation-bolts is sent with each engine.

The boiler is provided with a large dome—a most unusual addition to a vertical boiler. Not only this, but within is a dry pipe running to the top of the dome. By these means *dry steam* is secured and "priming" effectually prevented. The dome is encased in the smoke-chamber, thus preventing condensation and imparting additional heat to the steam on its way to the cylinder.

Hand holes are placed on every boiler, and ample provision is made for cleaning every part.

Fig. 36 shows the portable engine made by Messrs. Frick & Co., of Waynesboro, Franklin county, Pa., known as the "Eclipse" portable engine.

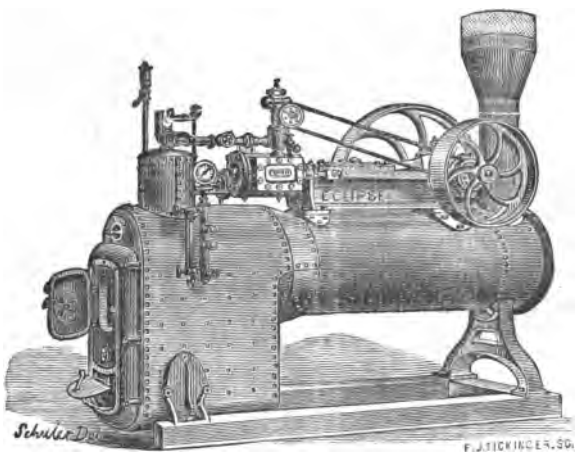


Fig. 36.

This engine is of the horizontal style, and is made with a bed, from entirely new and improved patterns. The entire engine can be readily removed from the boiler and placed on a suitable foundation, and used separately as a stationary engine when desired.

Cylinder and Steam Chest,

And the frame or bed, which comprises the cylinder heads, guides for cross-head, and the two *bearings* for *crank shaft*, all in one solid casting, thereby making it impossible for the important working parts of the engine to get out of line.

Shape of Bed

Is the half of a horizontal hollow cylinder, except a small portion of one end, which is an entire hollow cylinder with its one end closed by the formation of a flange or *cylinder head*, to which is bolted the *cylinder and steam chest in one casting*. This trough-shaped bed extends nearly to the pillow-blocks. Immediately under the pillow-blocks the bed is shaped similar to the steam-cylinder end, except that it is at right angles to it, in order to allow the crank to pass. Extending around the entire upper edge of the bed is a flange strengthening it, and serving as guide or cross-head.

The bed is bolted to brackets on the boiler, when used as a portable, or on a foundation when used as a stationary engine, by means of a flange running its entire length, which is widened under the pillow-blocks and at the steam cylinder end for that purpose; and the main part of the bed is connected with this flange by means of a web. The pillow-blocks and the widened flanges at the same end of the bed are connected for the purpose of strengthening them by means of vertical braces. The widened flanges at the other or steam cylinder end are connected with the main part of the bed in like manner, *all forming one solid casting*.

It will be observed that by this style of bed (which is trough-shaped) under the principal working parts, are caught all the oil, or drippings, from the bearings and stuffing-box, which would other-

wise drop on the boiler and make it very hard to keep clean. There is also an oil channel around the outside of both guides, leading into and conveying all waste oil into the inside of the bed. The drippings and waste oil in the bed are conveyed from the engine and boiler through a small tube provided for that purpose. By this arrangement the engine and boiler can, with little labor, be kept clean, and it will be found especially valuable where the engine is set up in a building where cleanliness is an object.

The *cylinder* and *steam chest* are made in one casting, which is firmly attached to the solid bed, and in perfect line in the manner above described; all the exposed parts being covered with felt, and handsomely jacketed with iron, which very much improves its appearance, and prevents radiation of heat —preventing the steam in the cylinder from losing its elasticity by condensation; the cylinder being bolted at its one end only to the bed, is allowed perfect freedom of expansion; and as the cylinder, steam-chest, slide-valve and piston-rod lengthen in the same direction, the engine will have the same lead and clearance when working as when cold; and by this arrangement of cylinder and bed, the working strain acts on a line through the centre, thereby relieving the engine from the powerful and unequal leverage incident to many defective modes of construction.

The Pillow-Blocks,

Or bearings for crank shaft on this engine, are of

the kind used on first-class stationary engines, being lined with the best quality of anti-friction metal, and provided with side brasses and adjusting screws for taking up all lost motion.

The Crank Shaft

Is double, extending far enough on either side of the engine to receive a pulley without interfering with the boiler. It is made of the best American forged-iron, without weld or seam, and is balanced by means of counter-weights, which produces a smooth and equable motion, so that the engine can be run at a high rate of speed without injury to its parts.

The Connecting-Rod

Is forged from the best refined wrought-iron, and has the proper proportions for the greatest strength, and is provided with boxes made of the best copper and tin composition, having very large bearing surfaces, and made adjustable to any possible wear, and the whole is fitted with the greatest accuracy and care, thereby making it very durable.

The Guides

Are of the kind so universally used on all the best locomotive and stationary engines, and have very long bearing surfaces for

The Cross Head,

Which is also of the locomotive kind, except that it has brass gibs, adjustable to any wear.

The Piston

Is of improved pattern, fitted with a metallic packing ring, which is self-adjusting, and readily adapts itself to any wear of the cylinder, needs no adjusting or setting, and will remain steam-tight with but little friction until the ring is worn out.

The piston-rod is made of steel and smaller than those made of iron, occupying less space in the cylinder, and consequently making the areas on each side of the piston more nearly alike.

The Pump

Is driven direct from the cross-head, and is bolted to the side of the bed. It has an improved brass valve-chamber with composition valves, and they are so arranged that by simply turning one screw either valve may be removed without disturbing the other or any of the pipe connections. The suction-valve also serves as a stop-cock in the suction-pipe, thus dispensing with an extra cock and several extra joints in the suction-pipe, consequently insuring greater certainty of pump to work. This valve is always open, and the supply of water to the boiler is regulated by the use of a waste-pipe and stop-cock in the discharge-pipe from the pump to the boiler, by which it is easy to regulate the amount of water required in the boiler.

The Heater

Consists of a large cast-iron pipe bolted near its one end to the steam-cylinder, is slightly inclined to

admit of draining, and is supported at the other end by a bracket on the bed. The advantage of this position is that the extremes of heat and cold, to which the heater is subject, cannot affect the engine in any way; while, if the heater were formed in the bed, the consequent expansion and contraction would affect the working parts by throwing them out of line. The exhaust steam from the cylinder passes through this heater in passing to the smoke-stack, heating the water in the feed-pipe (which passes two or three times its entire length) to a very high temperature before it enters the boiler, which makes it much easier to keep the pressure of steam to any desired point, and also entirely relieves the boiler from severe shocks caused by forcing currents of cold water into it, and saves considerable fuel.

The exhaust steam, after being utilized for heating the feed-water, discharges through a nozzle into the smoke-stack, which also greatly increases the draught and aids in extinguishing the sparks, thereby making the engine perfectly safe as regards fire.

The Governor

Is of the most approved kind, and is placed directly over its valve, which is perfectly balanced, making it direct-acting, obviating the use of levers and the consequent lost motion due to them. This governor being direct in its action, makes it act instantaneously, so that the most uniform speed is maintained under the most varying load and pressure of steam.

The Slide-Valve Rod

Has a guide outside the steam-chest, with large bearing surface.

The Eccentric

And its connections with the valve are fitted up in the most substantial manner, being provided with all necessary arrangements for taking up wear, and fitted with a degree of skill and accuracy that cannot fail to commend it.

A Tallow Cup

Enters the top of steam-chest, by means of which the piston and slide-valve can be lubricated without stopping the engine, and under full pressure of steam.

Self-Feeding Oil Cups

Are inserted on cross-head, slides, connecting-rod, eccentric, pillow-blocks, and all other parts where experience has found them necessary.

Air Cocks

Are placed on the pump, steam-chest, feed-pipe, etc., for the purpose of draining them, thereby preventing freezing and bursting of pipes in cold weather, which is a source of great trouble with many portable engines.

The Boiler

Is made of the best American boiler plate iron, in the style or pattern of a locomotive boiler, which secures

the greatest amount of heating surface and water space within given limits. The water space extends entirely around the fire-box and ash-pit, which is an improvement, both in economy of fuel and safety in keeping fire from dropping to the floor. Special care has been taken in allowing the proper proportions of fire surface, water capacity, and steam space, so that there is no danger from foaming or trouble from hard firing.

The shell is made of best Pennsylvania iron, of proper thickness, and makes a very strong boiler.

The furnace is made of best solid fire-box plate, which is seldom used in portables, making it safe beyond doubt.

The tube sheets are also of the best iron for this purpose, and are selected of the proper thickness, according to the size of the boiler.

The tubes are of the best American lap-welded, and set in the heads by the most improved process. The furnaces at the sides and top and bottom are braced in the most approved and strongest manner.

Special attention is directed to the shape of the furnace, the under side of which is semi-circular, forming an ash-pan around which the water circulates freely, preventing the accumulation and adhering of sediment in the part of furnace below the grate. The water legs of the ordinary locomotive boiler soon require renewing, on account of there being very little heat below the grates where the water is comparatively in a state of rest, thereby al-

lowing particles of mineral and earthy matter to deposit, which soon form a solid and compact mass and destroy the boiler. By rapid circulation of the water in the circular water bottom, these particles are kept in a state of solution, so that they can easily be removed from the boiler, by simply opening the blow-off cock, or removing hand-hole plates provided for that purpose. A boiler made on this style is also much stronger than others, and does not require a separate ash-pit, and can be run with as much safety from fire as a common stove.

The fire door is made double and lined with a perforated plate, and has also a register, which admits air, keeps the door from over-heating, and ignites the gases.

The boilers are furnished with a safety-valve, having composition valve and valve-seat, and will, therefore, never rust fast or stick to its seat, as is the case when made of iron.

On the side of the boiler near the steam dome is attached a handsome and first-class steam-gauge, and also a steam whistle, either of which can easily be removed, if required; and they are so arranged that they will not freeze up in winter.

The boiler is mounted on strong cast-iron saddles or legs, bolted to skids or timber frame running its entire length, and supporting it during transportation. They are also intended to be used as a permanent foundation, requiring no other setting. Nearly on top of boiler, and at an equal distance from centre,

are firmly bolted the saddles, having planed surfaces, on which is bolted the bed-plate of the engine, as shown; the one end of bed-plate, however, is not bolted direct to these saddles, but is so arranged that the boiler has perfect freedom for expansion without straining either engine or boiler.

Every boiler is thoroughly tested with water and steam pressure, and guaranteed to stand a cold water pressure of 150 pounds per square inch.

There is inserted in the crown-sheet of these boilers a fusible plug, the centre of which will melt out the moment the crown-sheet is bare of water, discharging steam and water into the fire, thus preventing injury to the crown-sheet from low water.

Gardner's Patent Tri-Cylinder Engine.

Fig. 37 is a transverse section of Gardner's Patent Tri-Cylinder Engine, showing the cylinders, pistons and connecting-rods. Also a broken section of steam and exhaust passages. It has many points of excellence that are apparent, and it will only be necessary to enumerate a few of the many advantages claimed for it. As the engine has no dead center, it can be started with the crank in any position. The connecting-rods being always in compression, there is no sudden blow or pound upon the crank-pin, however loose the fit may be, with the engine running at any speed. The working parts being entirely encased, they are protected and kept free from any dust or grit that may be around the engine, and are lubri-

cated constantly by the automatic oiler, which is placed upon the top cylinder, and which admits a drop of oil at each stroke of the engine, spreading it

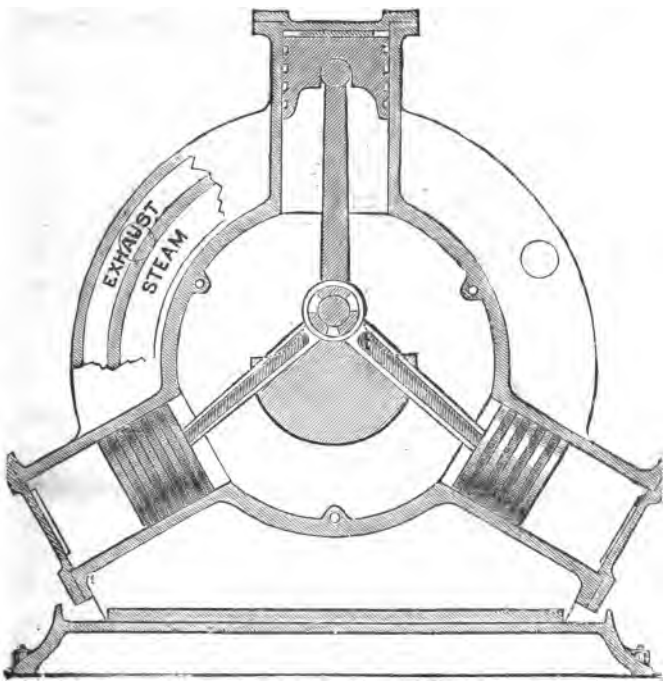


Fig. 37.—Gardner's Tri-Cylinder Engine, built by R. Dunbar & Sons, Buffalo, N. Y.

by the steam and centrifugal force to all of its working parts.

The details of construction are the result of long

experiment and careful study, combined with practice.

The pistons being deep, light, and well-packed, guide themselves in the cylinder, and are connected to the *phosphor-bronze* connecting-rods, the ends of which form the connection to the crank-pin.

On the end of each rod is a compensating box, which, in case of wear, can be replaced, making the connection as good as new. This arrangement admits of the engine automatically taking up her own wear, as the thrust is always direct on the crank-pin.

The moment steam is admitted to the piston it is communicated to the crank direct, without the friction attending the transmission of power to the different parts, as in the ordinary engine.

The piston will follow up its connection until worn out, it never leaving the bore of the cylinder.

The crank shaft is of steel, and is counterbalanced so as to insure steady running while the engine is at work, and it extends through a sleeve running through the pedestal, which has a long bearing on the pulley end, so as to reduce the wear to the minimum. On the front end of the shaft is placed a bevel gear to connect with the governor gear, making the governor a part of the engine itself, thereby ensuring a perfectly uniform motion to the engine. As the governor goes so must the engine. There are no belts to break or parts to give way (which often cause bad accidents), so that the governing power is

as perfect and constant as can be devised. All parts of the governor are accessible, and the speed of the engine can be changed instantly, while it is running, to any extent desired, within the range of the governor.

The only parts of the engine to pack are the three valve rods, which are very accessible, the packing cups being deep; so that when once packed a slight turn of the gland is all that is necessary, should any steam leak through them.

None but the very best materials are used in the construction of this engine. The form is unique, all angles and corners being avoided, and everything being circular, a free and easy movement is secured to all of its working parts. Its form also adds materially to its strength, and it requires less room and weighs less than any engine known of the same power and capacity. Every part is accessible, and the engine can be stripped and put together again in less time than the ordinary engine. Steam is introduced to either side of the throttle, as may be most convenient, and the exhaust can also be placed as conveniently as may be desired. The circular ring or belt of which the cylinders form a part, also forms the valve seats, and it will be observed that the valves and seats are as close to the cylinders as is possible. The passages in the belt or ring are of sufficient size to secure boiler pressure as near as possible to the valve, thereby obtaining the shortest possible passage of steam under the valve to piston in

cylinder with only the thickness of metal intervening between valve-seat and cylinder. Steam is cut off so as to work expansively in each cylinder, thereby securing all the power of the steam before delivery to exhaust, enough exhaust steam being compressed in each cylinder to sufficiently cushion-piston in going over centers, as well as imparting initial pressure on the piston the moment the valve opens to take steam. The steam-ports are made long and narrow, so as to reduce the throw of the eccentric to the minimum. The valve-rods are made of steel. The valve is a patent balanced valve. The high speed at which this engine may be run admits of immense development of power in proportion to its size, which is of special advantage in many cases, when, if additional power is required, it can be obtained immediately by giving the governor more speed. The governor-valve being balanced, the engine will respond promptly to the slightest turn of the thumb-screw on the top of the governor-head. When steam is in the public streets or where parties have buildings rented with power, this engine is of special importance in preference to the usual method of distributing power from floor to floor with one large engine. As, for example, if different parties are using power on each floor and any accident happens to the one engine, each consumer of power must necessarily stop until repairs are made, while by this method of putting an engine on each floor of sufficient power to do each one's work, no such liability to accident could occur, and

each party can stop or start as their business requires, thereby being subject only to the expense attending the running of their particular business.

Fig. 38 shows the style of portable engine which is manufactured by Messrs. Skinner & Wood, Erie, Pa.

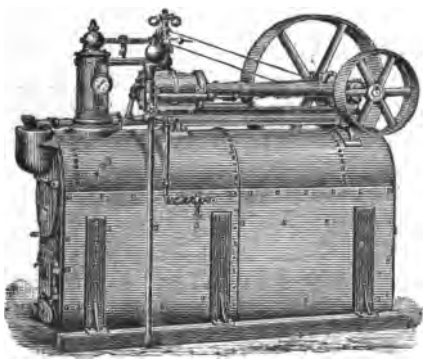


Fig. 38.

The frame is cast in one piece, with cylinder head and main shaft boxes, and on same plane with center of cylinder; the strain, therefore, if any, is in a direct line with piston-rod, and the evil is avoided of the engine getting out of line, so common with those built on the usual plan, having their different pieces bolted to the bed.

The bed is formed to prevent any drippings from reaching the boiler, with the assistance of the drip-pans, which are placed under the pump, valve-stem, shaft-bearings and eccentric. These devices deserve

special attention, for they ensure cleanliness. Every operator likes his engine and boiler to be clean and neat, and will take pride in keeping them so, unless discouraged by finding that his scraping and scouring of one morning is rewarded only by a repetition of it on the succeeding day. Under these circumstances patience ceases to be a virtue; the drip is allowed to accumulate, affecting the durability of the boiler and becoming an eyesore to all about it. With these drip-pans all oil and water from the engine is carried off through one pipe, and the boiler can be kept perfectly clean.

The shaft bearings are unusually large, and careful provision is made for taking up the wear in the direct line with the cylinder, and to ensure thorough lubrication. Driving pulleys can be placed on either or both sides of the engines.

The valve is the plain slide-valve, cutting off at five-eighths stroke, the point found most effective, and driven by eccentric.

The valve-rod has two square bearings outside of the steam-chest, with provisions for taking up the wear. Between these bearings connection is made with the eccentric-rod. This arrangement insures great durability. It is worthy of note that in many cheap engines the valve-rod has no bearings, thus permitting the valve to work loose and causing irregularity in the admission of steam to cylinder.

The piston has a ring packing, which adjusts itself by steel springs to any wear. These springs are

usually mounted on *iron* pins and secured by *iron* nuts, which are liable to rust and prevent springs from acting. In this engine the pins and nuts are of brass. The *follower* nut is also of brass, a point which will be appreciated by engineers who have tried in vain to remove an *iron* follower nut in the endeavor to get at the piston.

The guides and cross-head are what are known as the locomotive pattern, and admit of wear, being taken up by both upper and lower guides, thus keeping the cross-head in line. These are believed to be the best, though much more expensive, and for this reason they are found on but few of even the first-class engines.

The pump is driven by a cross-head, and has interchangeable brass valves and seats. It is thoroughly accessible, and every part can be reached without disturbing other parts of the engine. The heater in these engines is under the dome. The pipes are $2\frac{1}{2}$ inch wrought iron, and can be easily removed, if injured, and replaced at a trifling expense. These heaters it is claimed effect a saving of 20 to 30 per cent. in fuel.

The combined check, stop and relief valve is believed to be an arrangement never before placed on an engine, and was suggested by the great annoyance and damage incurred by the closing of the stop-valve between the pump and boiler, and neglecting to open it upon starting the pump, the result being that the weakest place must give way. As it is extremely

necessary to have a stop-valve between the pump and the boiler (for the purpose of shutting off communication with the boiler in case the pump valves need cleaning), the stop-valve is so constructed that when the valve is closed, communication is opened between the pump and the atmosphere, thereby relieving the pressure if the pump is started with valves shut. This is a very simple arrangement, and cannot possibly fail of working.

The crank is of heavy wrought-iron.

The safety-stop governor and self-oiling steel connecting-rod are important features in these engines.

The valve-rod, piston-rod, pump and eccentric-rods are of the best steel. The connecting-rod is also of steel.

The boiler is made entirely of the best wrought-iron, the shell being of $\frac{1}{4}$ inch charcoal hammered No. 1 American boiler plate. The heads are of the best $\frac{3}{8}$ inch flange iron, and the flues lap-welded. Instead of brick walls, the boiler has a heavy wrought-iron casing, lined its entire length and both sides with fire brick, and instead of a fixed bridge, one is used which can be moved to increase or diminish the grate surface.

The fire is built directly under the body of the boiler, where it is most needed, and, after passing along the entire length, returns again through the flues, the smoke escaping up the stack. This arrangement, known as the horizontal return-flue boiler, secures proper proportion of fire surface, water capa-

city, and steam-space, and the greatest economy in the use of fuel.

The fire-box is very large in proportion to the boiler, admitting the use of fuel which cannot be used in any other way, and effecting a valuable saving in its preparation, if it be wood.

The flues in these boilers are lap-welded; both ends are below the water level, and can be easily reached without disturbing the boiler, engine, or connections.

A final specific feature found in these boilers is the adjustable and smoke-consuming bridge wall. This can be moved backwards or forwards, enlarging or contracting the fire-box, and adapting it to any fuel.

Fig. 39 shows the portable engine and boiler known as the "Bookwalter Engine," which is a great favorite in the South and West. The cut shows the entire machine so plainly that a detailed description is almost unnecessary, even for the most inexperienced in such matters. The boiler is what is known as the upright tubular boiler, and in the arrangement of the tubes, furnace, steam-space, etc., is very similar to Fig. 27.

The engine is simplicity itself. The cylinder is attached to the boiler in a vertical position, which prevents the usual wear and tear of the cylinder and piston when placed horizontally.

The crank-pin, valve-stem, piston-rod and slide, are made of steel. The journal boxes are of brass

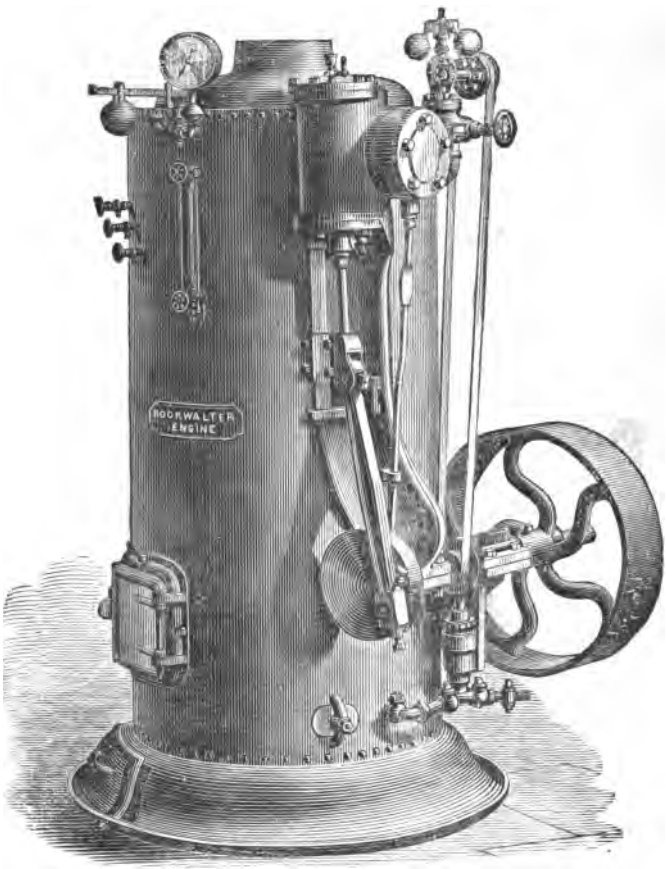


Fig. 39.—The Bookwalter Engine.

lined with Babbitt metal. The stuffing-box gland is a brass screw gland, which prevents the cutting of the piston-rod in case the slide should get out of true.

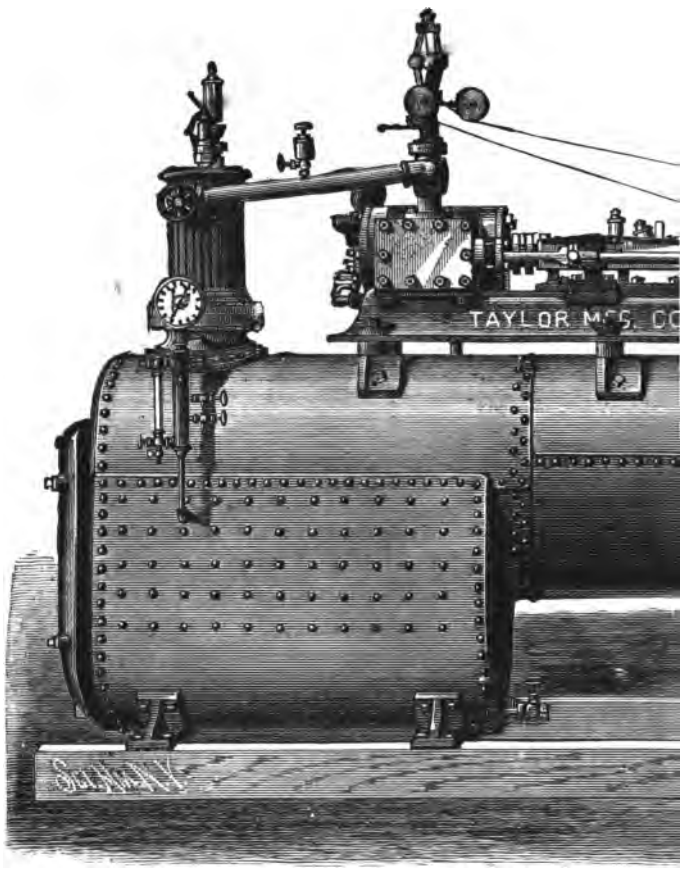
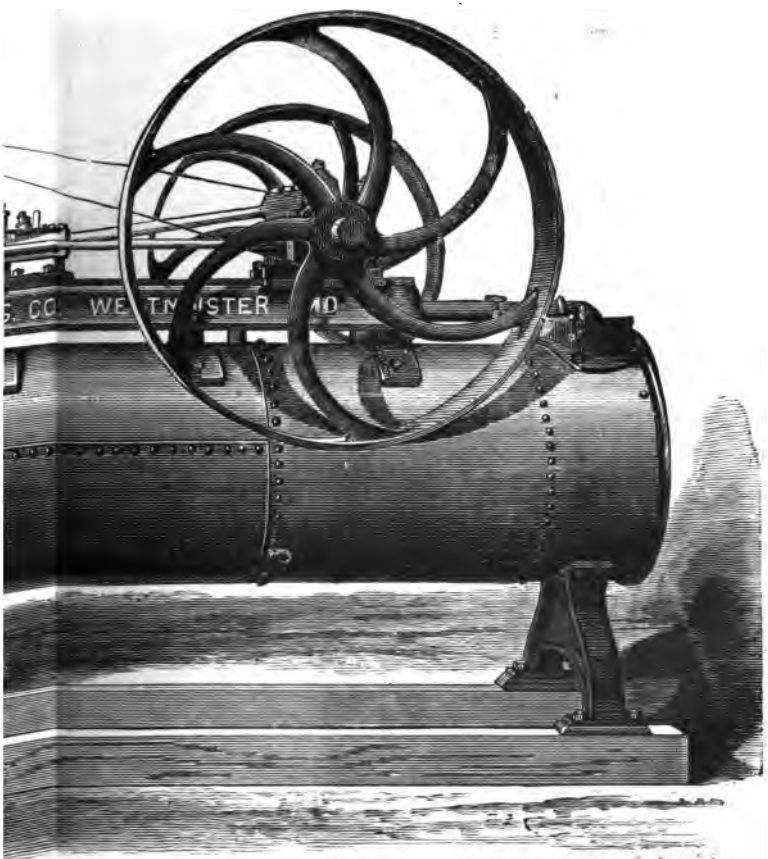


Fig. 40.—Portable Engine made by the Taylor M



LOR MANUFACTURING COMPANY, WESTMINSTER, MD. Page 155.

The valve is a plain slide-valve with sufficient lap to give a good cut-off, and at the same time give the exhaust steam an early and free release. The piston is of the usual kind, with cast-iron rings set out by steel springs. The steam-gauge, safety-valve, governor and glass-gauge are all of the kind in general use, and need no special description. The whole machine is plainly but compactly built, while the material and workmanship are first-class. The whole reflects great credit upon the builders, Messrs. James Leffel & Co., Springfield, Ohio.

Improved Portable Engine.

Fig. 40 represents a portable engine made by the Taylor Manufacturing Company, of Westminster, Md. These engines have been in the market since 1857. The Taylor Manufacturing Company have purchased all of the patterns of the Utica Company, and have made many very decided improvements in details of construction while holding to the original well-tried principles of the engine.

This engine answers as a portable engine on the boiler, and it can be taken off and set upon a separate foundation and used as a stationary, and when so used it possesses advantages over the ordinary side crank stationary engine, as it has a compound or center crank supported by two ample bearings having gibs for adjustment. The journal boxes are of the kind known as the four-quarter box. They are bolted to the bed-plate, which sustains the working

strain of the engine and keeps all the parts in line. When the engine is used as a portable, the bed-plate is secured to the boiler by means of stands or brackets, bolted to the boiler. The bolts that secure the frame to the brackets are made so as to allow for the expansion and contraction of the boiler without producing any strain on the engine bed. The guides are the usual locomotive pattern, and the cross-head has large and ample wearing surfaces. The connecting-rod is made of the best hammered iron, straps being keyed and bolted and well fitted with gun metal boxes. The box in the crank end of the rod is made square to prevent rocking motion. The crank shaft, which is of good size, is forged of the best hammered steel. The fly-wheels are heavy, and carefully balanced. Much care is taken in the casting of the cylinder so as to have good wearing metal. The piston is fitted with the usual packing, all joints of the rings being carefully ground and fitted so that the rings will adjust themselves to the surface of the cylinder. The slide-valve is of the usual D-valve pattern, proportioned upon correct principles. The boiler is economical in the use of fuel, and the engine uses the steam to the best advantage. The Pickering governor used in connection with this engine is provided with a double valve that does not stick, and also with a stop motion that prevents the engine from running away in case the governor belt breaks. The speeder attachment is so arranged that the speed of engine can be changed fifty revolutions or less with-

out altering the size of the pulleys or stopping the engine. The stop-motion is a very valuable feature, and will prevent such accidents as occur from the running away of the engine. The engine is fitted with a pump or inspirator as may be desired, and is provided with a heater in the bed-plate directly under the cylinder. The exhaust steam enters the heater, heating the feed-water and escapes through a pipe into the smoke-stack. The heater being contained in one end of the frame overcomes the objectionable features of expansion and contraction of the frame or bed, a common fault with many engines that have the heater running the whole length of the frame.

An exhaust nozzle of peculiar construction is placed on the end of the exhaust pipe in the smoke-stack, by which the effect of the escaping steam on the draught can be regulated at will and made to produce a very strong draught if desired. The boiler is made of the best Pennsylvania charcoal iron, carefully fitted, and double riveted where the shell is connected to the fire box; all flat surfaces are closely stayed; the holes punched so as to avoid the use of the drift pin; the crown-sheet is stayed with crown-bars upon the same principles now used by the best locomotive builders, and is provided with a safety fuse plug that melts out in case of low water, and puts out the fire, thus preventing the burning and injuring of the crown-sheet and providing against explosion occurring from that cause. The flues are three inches in diameter, of the best American lapwelded make. The

boiler is provided with a large dome, securing large storing capacity for dry steam, and has a steam blower for blowing fire; it is securely mounted on strong stands and sills, and is provided with three gauge-cocks, glass water-gauge, steam-gauge, two top-valves, a steam whistle, steam flue cleaner and fire-irons, twenty feet of smoke-stack, and double spark-arrester. The engine is provided with automatic glass oilers and cylinder lubricator, a full set of wrenches, oil can, and, in fact, everything that should be found on a perfect engine. This engine represents only one style or class of portable engine, in addition to which this company manufacture the well-known dry-steam engine, the Utica adjustable cut-off valve stationary engine, saw-mills, and the clipper vertical engines.

The Watertown Portable Engine.

The patent portable engine shown in Fig. 41, and built by the Watertown Steam Engine Co., Watertown, N. Y., is the result of thirty years of careful study and repeated experiment: there is no point in its design and construction that has not been thoroughly proved by use. At the same time it has maintained itself fully abreast of the times in the march of inventive and scientific improvement. There is no recognized need of the steam user for which it does not provide, and there is no improvement, convenience or addition of decided advantage to the modern steam-engine that is not found in this engine.

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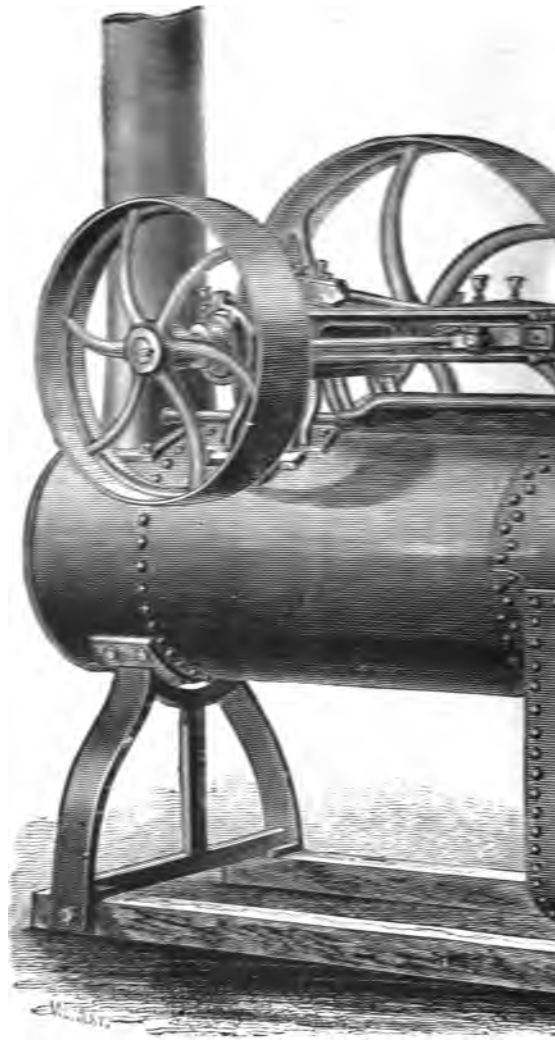
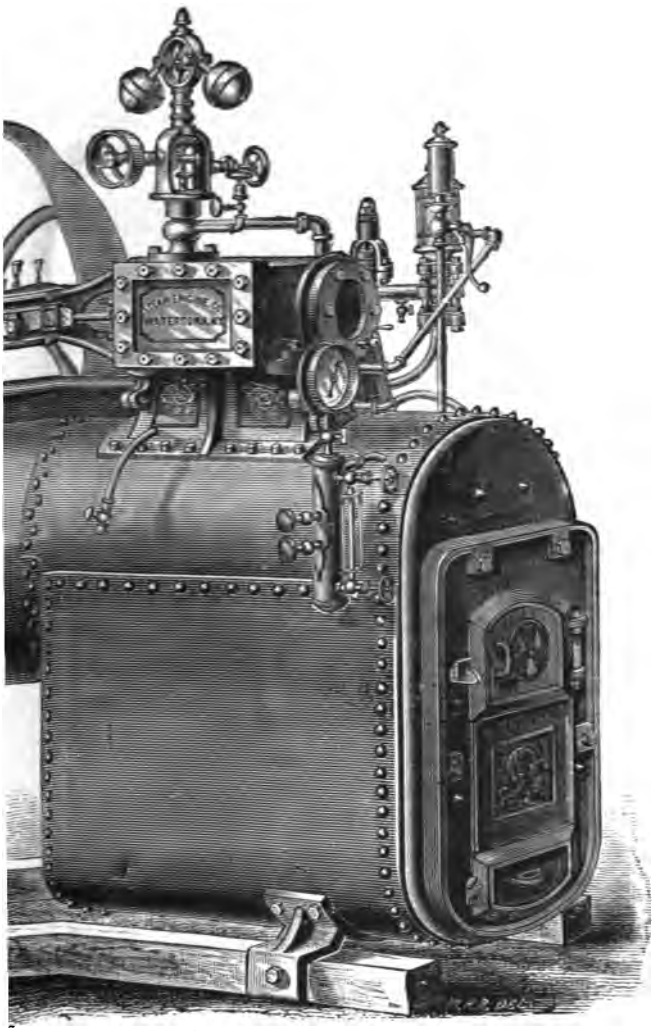


Fig. 41.—The Watertown



:KTOWN PORTABLE ENGINE. Page 158.

While we recommend the stationary engine, where its use is advisable, and especially for large powers, there are, nevertheless, many instances where the temporary nature of the business, the necessity for occasional moving, the small amount of power required, the cost and inconvenience of brick setting, the immediate need of power, or other causes, make a portable engine the more desirable.

Among the good points in the design of this engine are the following:

The cylinder is placed directly upon the dome, which has a large planed surface to receive it. By this means the cylinder and steam chest are kept constantly at a high and even temperature, the steam passages are reduced to a minimum length, and the condensation of steam in the cylinder and steam chest is effectually checked.

To this mainly is due the remarkable economy of fuel for which these engines are noted, and from this they have acquired the name of the Dry steam-engines. In addition to this the engine is lagged with close fitting iron staves.

A further advantage resulting from the position of the cylinder lies in the fact that the steam is drawn and used at the highest point of the boiler. There are no long pipes where the steam can condense, and from which it must drain into the cylinder and steam chest. Every engineer knows that water in the cylinder is a most fruitful source of evil, producing knocking and rattling, and sometimes breaking a piston or cylinder head.

The position of the cylinder in this engine goes a long way towards obviating this difficulty, not only preventing "foaming or working water," but also draining the water of condensation back in the boiler instead of into the working parts of the engine.

Another point of value is found in the centrai position of the engine on the boiler. The strain from the working of the engine is thus received by the boiler in the direct line of its greatest strength, entirely avoiding the cross or diagonal strain on the riveted seams to which side-saddle engines are so subject. The connecting rod takes hold of the centre of a double crank shaft, with wide bearing on either side. It carries two pulleys, balancing the weight and permitting the engine to drive two machines at the same time, without counter shaft. A solid and substantial bed-frame holds both bearings for the main shaft, the guides and the cylinder all in perfect line. The main objection to the use of a portable instead of a stationary engine, is that the working and straining of the engine is at variance with that of the boiler, thus eventually tending to throw the engine out of line, or to twist or rack the bolts by which it is held. This engine is entirely free from these objections; it differs from some other portables in that it does not depend for support upon the shell of the boiler, being neither hung to its side by bolts, nor supported upon a line of brackets, with or without the intervention of a bed-plate upon the shell of the boiler. The engine is planted upon the broad

solid surface of the dome, and has no other connection with the boiler except the brackets which steady the rear end of the frame. Moreover, by this method of supporting the cylinder upon the dome, the use of one or more brackets bolted over the fire box end of the boiler is avoided, and so lessen the liabilities to racking, strain and leakage; at the same time the bed-plate is so constructed that by loosening a few bolts the engine can be removed from the boiler and set up on a separate bracket.

The shape of this bed frame is such as to surround the working parts and protect them from dust or injury, *inclosing* the bearings and guides, and not merely *supporting* them. By this means is saved much of the knocking in the main boxes, that often proves so troublesome when the pillow blocks and guides are bolted to the top of the frame.

The position of the heater is in the dome. In this position it cannot be reached by frost, its variations of heat and cold cannot affect the working of the engine, and it is readily accessible in every part, at once in the hottest position, and yet entirely out of the way.

It so frequently becomes necessary to change the speed of the engine, either by reason of a change in the power required, or the addition of new machinery, or a new arrangement of gearing, that the builders have invented and added to this engine an adjustable speeder, with which, by simply turning a hand wheel, the speed can be increased or dimin-

ished 50 or 100 revolutions, without stopping the engine.

They have also added a perfect stop motion, which, on the breaking or slipping of the belt, will, by the force of its own weight alone, shut off steam and stop the engine. There are no cams, levers or complicated work to produce this result; there is no possibility of its failing to work promptly and with perfect accuracy.

The governor is further provided with a self-oiling device which keeps the working parts constantly lubricated and prevents the sticking, binding and consequent failure to govern properly, which shows itself after the first few months in so many otherwise reliable engines.

The pump, an important part, but too often neglected, is especially sure and reliable: at the same time it is so simple and easily accessible that by the removal of two bolts, it can be taken entirely to pieces while the engine is running.

The pipes of the pump and heater are so arranged that when it is not necessary to deliver water to the boiler, it may be pumped through the heater and be returned to the tank or barrel; by this means the feed water may be heated to a very high degree. The supply of water to the boiler may be perfectly regulated, and the pump need never run dry.

A hose is attached to the pump, by means of which water may be thrown a considerable distance—an invaluable device for laying the dust, or putting

out an incipient fire. Air-cocks are also placed in the pump, heater and pipes, for the purpose of draining them and preventing freezing and bursting of pipes in cold weather.

We call particular attention to the fact that the joints of the cylinder are all ground, not packed; all bearings, journals and wearing surfaces are ample, and are all provided with oil-cups. All the working parts are made so as to be easily adjustable to any wear. All bolts, nuts and screws used about the engine are of standard size and thread, and in case of emergency, can be replaced at any good machine-shop.

The piston-rod, governor-arms and rod are of steel, the connecting-rod of best wrought-iron, with boxes and straps milled by special machinery.

All parts of the engine are made to standard gauges and templates, and are readily duplicated.

The boiler upon which the efficiency of the engine so largely depends, is designed and built with special reference to the two great requisites, *economy* and *safety*. Repeated experiments and careful study have shown how to secure the greatest possible efficiency, with the least consumption of fuel.

Among the points in the construction of the boiler looking to this end, we may note the following:

First. The circulating water bottom. This provides for the circulation of the water in the boiler and its more rapid conversion into steam, prevents the accumulation of sediment where it cannot be

reached, and prevents the escape of ashes into the engine-room.

Second. The fire-box is of unusual size, and at the same time the tubes are of less diameter than is common in other engines. An extra large water surface thus comes in immediate contact with the flame, which is also slightly retarded in its progress to the chimney by the contracted area, and transmits more of its heat to the water.

Third. The shell of the waist is of the full diameter of the fire-box. Some builders, in the attempt to cut off dead water, as they term it, make the mistake of throwing away at least three times the amount of live steam room. It is claimed that there is a greater economy in this design (though at an increased cost to the builders) as well as of its freedom from working water and foaming.

Fourth. These boilers are all made with an open front. There are no wrought or cast door rings about which sediment can collect or leaks appear, nor is the cold air on its way to the furnace brought at once in contact with the heated plate. By the removal of four nuts the entire fire-box is laid open for cleaning and repairs. The arrangements for regulating and directing the draft, are new, and especially commendable.

Fifth. The exhaust steam is carried into the smoke-box—killing the sparks and aiding the draft, but, unlike some other engines, the steam is carried to the level of the *lowest* flues. By this is secured an even draft, which prevents the lodgment of ashes and cin-

ders in the bottom tubes, and adds largely to the effective power of the boiler.

As regards the safety of these boilers, we note:

First. The flat crown sheet—which is also braced and stayed by heavy wrought-iron crown-bars, in the form of a truss—enabling the sheet to stand an enormous pressure.

Second. Probably no point of a boiler is so severely strained as that where the waist and fire-box unite. In a large majority of explosions this is where the first giving way occurs. For this reason, is not only great care used in the selection of material and the workmanship, but this seam is *double* riveted, thereby adding some thirty per cent. to its effective strength.

Third. Every boiler is supplied with a fusible plug in the crown-sheet, which will melt in case of low water and permit the steam to put out the fire.

Fourth. The "locomotive-pop" safety-valve is furnished with every engine. The old style ball and lever-valve have been discarded, because found inaccurate—rarely closing within five pounds of where it opened—unreliable, rusting and sticking to its seat unless constantly looked after, and very apt to be tampered with, overlooked, or fastened down by the engineer. The new valve does not stick or bind, cannot be altered from the pressure at which it is set, and can be depended on to open and close in exact accord with the steam-gauge.

Fifth. The greatest possible care is exercised in regard to both material and workmanship. A careful examination of every plate is made before it is allowed

to go into the boiler; the patterns are so carefully proportioned and accurately made that the sheets come together without straining, drifting, or twisting. The bracing, staying and riveting is done in the most thorough manner. The tubes are best American lap-welded, and are expanded and beaded by a new improved process.

The smoke-chamber is made by extending the shell of the boiler; there are no joints through which either ashes or sparks may escape. It is provided with a large iron door for cleaning the flues—hand-holes are placed in the lower part of the boiler for purposes of cleaning.

Every boiler is thoroughly tested as soon as completed, and when the entire engine is finished it is fired up and again tested, being run for several hours at a high pressure, under a heavy load, until it is known that every part is perfect.

Fig. 42 represents a style of portable engine designed expressly for use in dairies, cheese factories, laundries, printing offices and small manufactories where a light power is required, that shall be at once economical, safe, reliable and easily cared for. It is placed centrally upon the boiler, balancing the weight, avoiding side strain, and carrying two drive pulleys, one on each side. The cylinder is placed upon the dome, with short and direct steam passages. By this means the condensation of steam is effectually guarded against, and foaming or working water into the cylinder is prevented.

The governor which is used on all these engines is provided with an automatic stop motion, which will

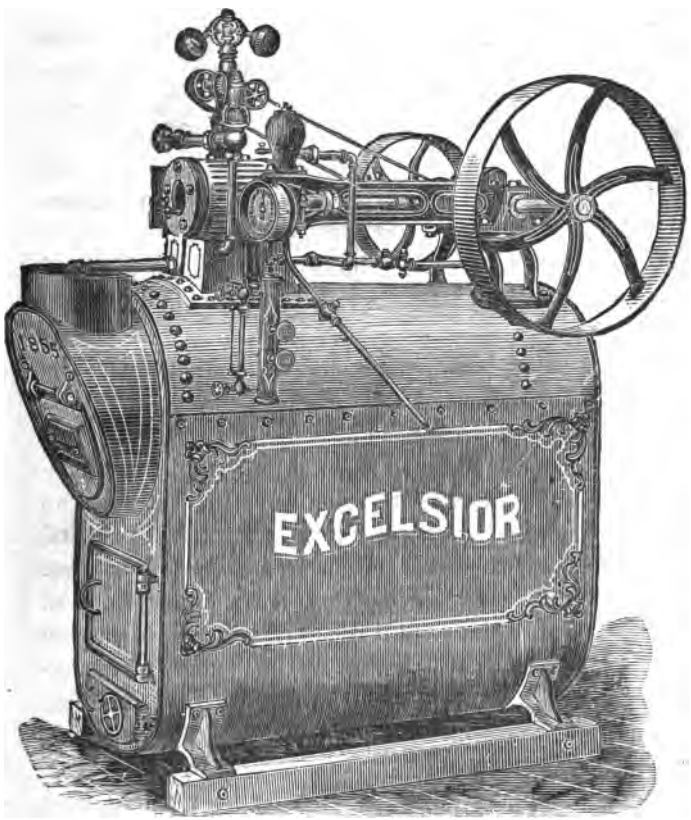


Fig. 42.—The Excelsior Dairy Engine, Built by the Watertown (N. Y.) Steam-Engine Co.

instantly shut off steam in case the belt should slip or break; also a spring-speeder, by which the speed of

the engine may be adjusted, while the engine is running, to meet the requirements of the work to be done. The governor has also a self-oiling device. The pump is very reliable; it is easily taken apart, is simple in construction, and is provided with abundant means for cleaning, packing or draining. All the working parts are inclosed, protected and held in line by a substantial iron bed or frame.

All these engines are supplied with a "pop" safety-valve.

The material used in both boiler and engine is of the best quality; the workmanship is first-class in every particular.

The boiler is of the return tubular pattern. The heat passes under the boiler, through its entire length, and returns through the flues to the smoke-chamber. The furnace has a shell of heavy wrought-iron, lined with fire-brick for its entire length. There is no crown-sheet and no water leg. The lowest point of the boiler is that directly over the fire. For these reasons it is peculiarly safe from explosion, and adapted for use where it is not convenient to employ the entire time of the engineer in the care of his engine. The fire-brick are easily removed or replaced, and can be removed when burnt out, at small cost. In this, there is an obvious advantage over the water leg, which, when burned, can only be repaired with considerable difficulty and expense. A hand-hole is provided, through which every part of the boiler can be reached.

The furnace has an adjustable bridge-wall, adapting it to the use of different kinds of fuel. It is provided with large double doors, making every part perfectly accessible for cleaning or repairs.

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transportation, with great strength at the same time. It may be moved where needed, and can be used thus to run saws for sawing lumber, the threshing-machine for threshing grain, the cotton-gin for separating the cotton fibre from the seed, or whatever other labor may be required. This engine is indeed a model for

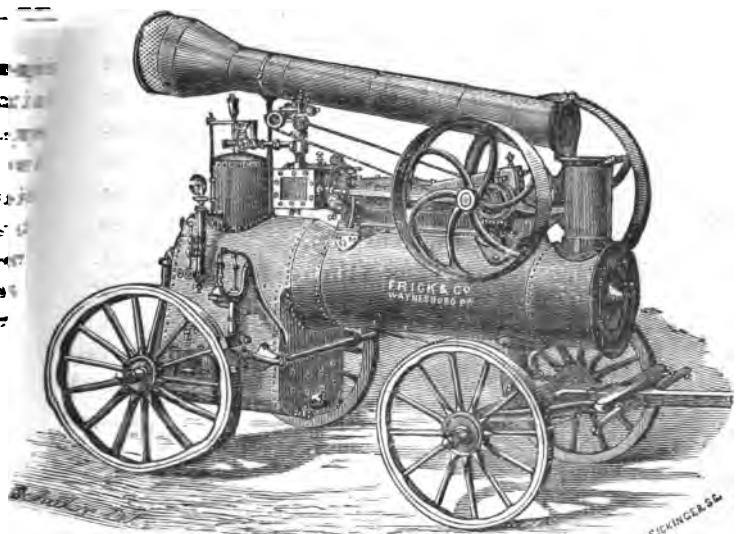


Fig. 43.—The Eclipse Agricultural Steam-Engine.

efficiency, simplicity, durability, economy, and safety. It is of the horizontal style, while it can be easily removed from the top of the boiler and placed on a suitable foundation, and at any time when desired, can be used as a stationary engine.

A great element of strength is that the cylinder-

head, guides for cross-head, and the bearings for crank-shaft, are all cast in one solid piece, so that it is utterly impossible for the important working parts ever to get out of line. The bed on which the working parts rest is bolted to brackets on the boiler when used as a portable, or a foundation when used stationary. One of the incidental advantages of this solidly-formed bed is that it receives all the oil and drippings from the moving parts, which otherwise would drop on the boiler, and make it difficult to keep it clean, while an oil channel leads this oil away through a small tube provided for that purpose.

All the exposed parts are covered with felt and jacketed with sheet-iron, so as to prevent loss of heat by radiation, and at the same time improve the appearance. The precaution is taken to bolt the steam-cylinder at one end only to the bed, so as to allow it freedom of expansion; and as the other parts lengthen in the same direction, the engine has the same lead and clearance at all temperatures. The crank-shaft is double and extends far enough at either side to receive a pulley or fly-wheel, which will rotate free of the boiler. It is made of good forged iron. The piston has a metallic packing, self-adjusting, so that it will always fit while wearing out; the piston-rods are steel, and therefore smaller than those of iron, which diminishes friction and increases the working area of the piston.

The boiler, that most expensive and most important part of any engine, is made in the locomotive style,

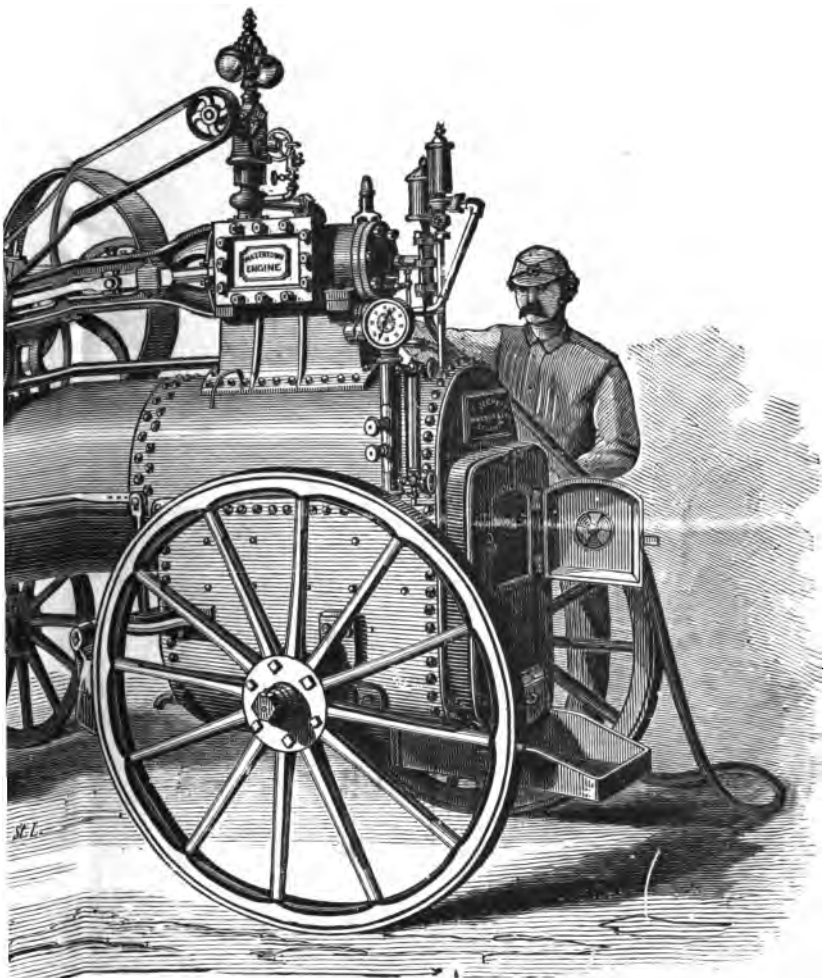
securing the greatest possible amount of heating surface and water space, combined with the smallest possible amount of bulk. The shell is made of the best Pennsylvania sheet-iron, and the tubes of the best lap-welded iron. The under side of the furnace is semi-circular, forming an ash-pan around which the water circulates freely, preventing accumulation and adhesion of sediment in the part of the furnace below the grate. The makers of this engine had noticed that the water-legs of locomotive boilers are subject to the adhesion of scale, which is very injurious to the boiler, and that this is caused by the shape of the furnace bottom, which causes stagnation of the water there; the circular water-bottom causing a circulation, removes this cause of harm. We mention these details only as a few specimens of the many precautions which the makers found necessary to take, in order to produce a really good and reliable engine.

The smoke-stack is hinged, for the double purpose that it should be out of the way when storing the engine under shelter, and to avoid the shaking of the long perpendicular cylinder during transportation. It has also a spark-arrester, so that even straw when placed on the top of it will not ignite. The same safety exists below at the ash-pan, which is provided with a close-fitting door, which can be closed if found advisable. Further, there are a suction-hose, strainer, steam and water-gauges, gauge-cocks, safety-valve, steam-whistle, governor, etc. In fact, it is a most

complete agricultural engine, and we do not doubt that the day is not far distant when such an engine will be judged as necessary on every large farm as any other farming tool.

Fig. 44 shows Bradford's Excelsior Portable Engine. In the Excelsior engine the dome of the boiler contains the heater—the base of the cylinder being joined to the top of the dome by a large planed surface. The heat of the boiler is imparted to the cylinder, which, being lagged also with close fitting iron staves, effectually checks condensation of steam, and makes the engine very economical in the use of steam and fuel. The wrought shaft having double crank and carrying two pulleys, the frame bears the two main boxes, and is joined to the cylinder so that the strain is central, thus avoiding the side strain which single-pulley side engines are subject to. These engines are furnished complete with all attachments, and every boiler is fully tested before leaving the shop. There is no part of either boiler or engine that cannot be removed, examined, and replaced in a very brief time. The frame cylinder head guides and boxes for main shaft are cast in one piece, avoiding all strain, and rendering it next to impossible for these parts to work out of line. The boilers are well-proportioned, are large and strongly made. All of them are fitted with "pop" safety-valves, which are as reliable as a steam-gauge. If the belt breaks or runs off, the governor stops the engine at once without jar or strain. The speed is

Fig. 44.—BRADFORD'S EXCELSIO



XCELSIOR PORTABLE ENGINE. Page 174.

adjustable, and can be changed to suit the work, 100 turns faster or slower, without stopping the engine. All parts of the engine are interchangeable, and can be duplicated at any time.

CHAPTER V.

STANDARD AMERICAN STEAM FIRE-ENGINES.

THE history of the various methods and appliances for extinguishing fires contains much of interest. The earliest notice of machines used for this purpose is in some allusions of ancient Roman writers to an apparatus, nowhere described, called a "sipho," while next we hear of a Roman architect who utilized the gut of an ox as hose, having a bag filled with water affixed to it; by compressing the bag, the water was forced through the tube. In early periods of English and French history the chief protection against fires consisted in the care with which those used for domestic purposes were managed. The curfew bell was sounded at eight o'clock as a signal for the extinguishing of fires. Later on, in 1518, we read of "instruments for fires," and "water syringes useful at fires," being in use at Augsburg, Germany; but the first fire engine of which we find any account was constructed at Nuremberg in 1657. It is described as being placed upon a sledge two feet long and four broad. It had a cistern eight feet long, four feet high, and two feet wide. It was moved by twenty-eight men, and forced a stream of water an inch in

diameter to the height of eighty feet. The cylinders lay in a horizontal position in a box. There was no air-chamber, nor anything more than a short, flexible discharge-pipe. A quarter of a century later leathern hose was first introduced. In England, at the close of the sixteenth century, the only engines known were "hand squirts," or syringes made of brass, and holding two or three quarts of water. Each one required the labor of three men, one on each side to hold the instrument steady with one hand and to direct the nozzle with the other, while the third man worked the plunger. When discharged, the piston was taken out and the nozzle was dipped in water, which flowed in and filled the body. This device was afterwards fitted to a portable cistern, and furnished with levers for working the piston. Later on, hand engines were introduced into that country, from whence they were shipped to the new world, improvements following, until in 1830 the first steam fire engine was invented by Mr. Brathwaite in London. This first engine was barely 6 horse power, weighing a little over 5,000 pounds; was furnished with an upright boiler, in which steam was generated to a moderate working pressure in 20 minutes, and was capable of forcing 150 gallons of water per minute from 80 to 90 feet high. But in the half century which has elapsed since the invention of this machine what mighty improvements have followed! Instead of 150 gallons per minute being thrown 90 feet, by the use of a first-size Silsby, 900 gallons can be thrown 325 feet.

The first attempt made in the United States to construct a steam fire-engine was that of Hodge, who built one in New York in 1841. It was a strong and very effective machine, but was far too heavy for rapid transportation. The late I. K. Fisher, who throughout his life persistently urged the use of steam-carriages and traction-engines, designing and building several, also planned a steam fire-engine. Two were built from his design by the Novelty Works, New York, about 1860. They were "self-propellers," and one of them built for the city of Philadelphia was sent to that city over the country roads, driven by its own engine. The other was built for and used by the New York Fire Department, and did good service for several years. These engines were heavy, but very powerful, and were found to move at good speed under steam, and manœuvre well. The Messrs. Latta, of Cincinnati, soon after succeeded in constructing comparatively light and very effective engines, and the fire department of that city was the first to adopt the steam fire-engine definitely as their principal reliance. This change has now become general.

The steam fire-engine has now entirely displaced the old hand-engine in large cities. It does its work at a fraction of the cost of the latter. It can force its water to a height of 225 feet, and to a distance of more than 300 feet horizontally, while the hand-engine can seldom throw it one-third these distances; and the "steamer" may be relied upon to work at full power many hours, if necessary, while the men at the

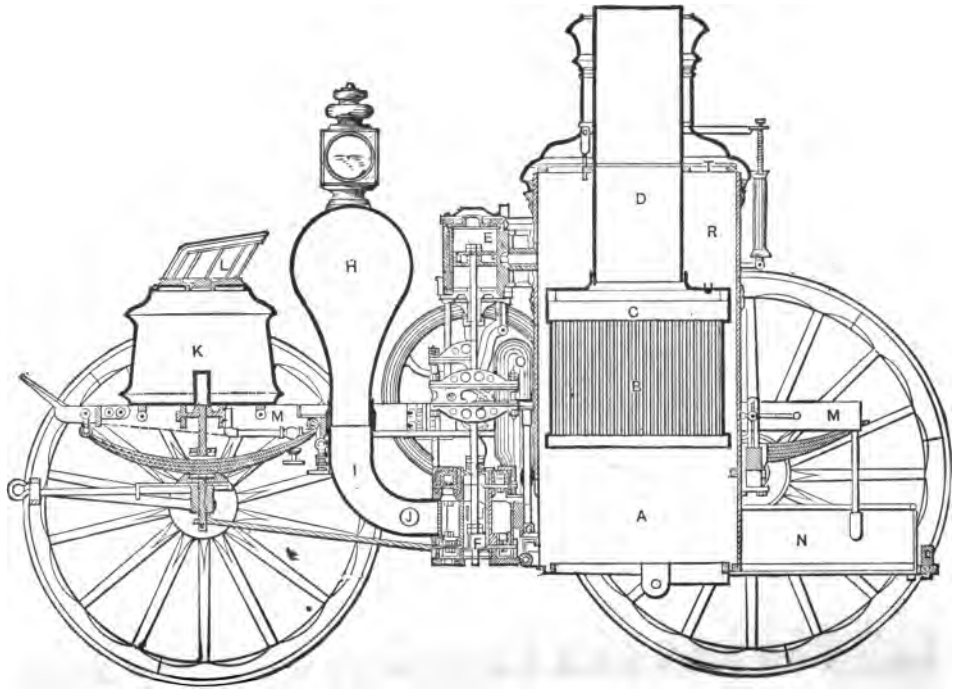


Fig. 45.—THE AMOSKEAG STEAM FIRE-ENGINE.—SECTION. Page 179.

hand-engine soon become fatigued, and require frequent relief. The city of New York has forty steam fire-engines; Philadelphia, twenty-eight.

In the steam fire-engine (Fig. 45), reciprocating engines and pumps are adopted, as shown in section, in which *A* is the furnace, and *B* the set of closely-set vertical fire-tubes in the boiler; *C* is the combustion-chamber; *D*, the smoke-pipe; *R*, the steam-space; *E* is the steam-cylinder, and *F* the pump, which is seen to be double-acting. There are two pairs of engines and pumps, working on cranks, set at right angles, and turning a balance-wheel seen behind them. *G* is the feed-pump which supplies water to the boiler; *H*, the air-chamber which equalizes the water-pressure, which reaches it through the pipe *I*, *J*. *K* is the feed-water tank, under the driver's seat, *L*, which, with the engine and boiler, is carried on the frame, *M*, *M*. The fireman stands on the platform, *N*. When it is necessary to move the machine, an endless chain connects the crank-shaft with the rear wheels, and the engine, with pumps shut off, is thus made to drive the wheels at any desired speed. A self-propelling engine by the Amoskeag Company has the following dimensions and performance; weight, 4 tons; speed, 8 miles per hour; steam-pressure, 75 pounds per square inch; height of steam from $1\frac{1}{4}$ inch nozzle, 225 feet; $1\frac{3}{4}$ inch nozzle, 150 feet; distance horizontally, $1\frac{1}{4}$ inch nozzle, 300 feet; $1\frac{3}{4}$ inch, 250 feet—a performance which contrasts wonderfully with that of the hand-worked fire-engines, which these engines have now superseded.

New Double Cylinder Steam Fire-Engine.

Fig. 46 shows the Double Cylinder Steam Fire-Engine, manufactured by the Clapp & Jones Manufacturing Company, of Hudson, N. Y.

The pump is of novel construction, and is so arranged that by taking off the heads (which can be done in less than ten minutes), the valves are taken out at the same time, making it very convenient for repairs or cleaning out, if either is required. The arrangements and proportions are such, and the displacement by the plunger so large in proportion to the space at the ends of the pump, that water can be lifted to a very great height. The pump is made entirely of composition (copper and tin), with no iron parts to rust, and is so constructed as to require no leather packing or springs. By introducing the water in the centre of the front head, there is the advantage of an equal distribution of the water through the annular space to all sides of the pump cylinder and valve chambers, making a very free water course to the valves. The pump is double acting, and both ends are alike, so that the valves from one end will fit perfectly in the other.

The boiler has great steaming capacity, and is provided with a peculiar arrangement for the circulation of the water, which is of the highest importance in boilers that operate so quickly, and are required to make so much steam in so small a space as is necessary in steam fire-engines. The boiler is so constructed that every part can easily be reached in case repairs

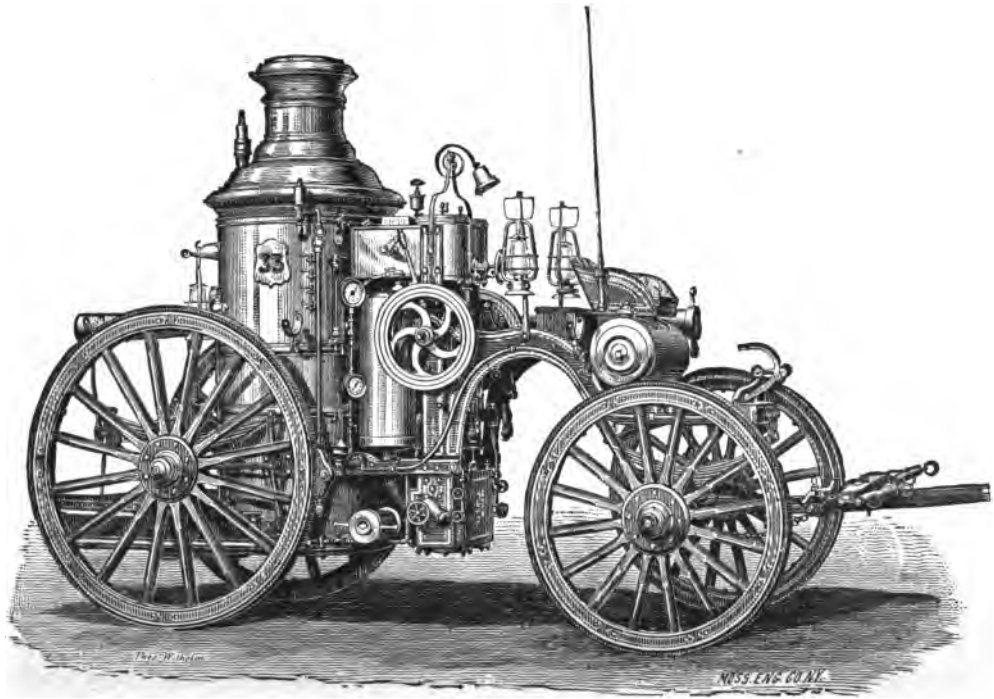


Fig. 46.—Double Cylinder Steam Fire-Engine. Page 180.

are needed. These boilers are claimed to bear the strongest firing without the least danger of overheating, and to make all the steam that can be used, working with an open throttle while doing the hardest possible work.

These engines are so arranged that the centre line of pressure comes in the centre of the frame work, giving the greatest strength with the least weight of material. The whole construction of the engine is simple, therefore they are not liable to get out of repair, and do not require an engineer so well skilled as more complicated machines.

The Holly Rotary Engine

is shown with head removed in Fig. 47. Its construction and mode of operation will be apparent from the following description:

The engine consists of a pair of corrugated cams running together within an elliptical steam-tight case. The steam enters at *A* and exhausts at *B*, turning the two cams, *C* and *D*, in its passage. The ends of the long teeth are packed by blocks of metal inserted into the grooves and pressed out by springs. These can be taken out and replaced in a few minutes, by means of openings in the sides of the case, entirely preventing the necessity of taking the engine apart. The sides of the cams are turned to fit the case, and, while being steam-tight, are so arranged that not only due allowance is made for contraction and expansion, but any little wear there may be after years of service can be easily taken up in a very short time.

Simplicity of Engine.

As will have been seen, the moving parts are two in number, and friction and wear are reduced to a minimum. Slide-valves, valve-rods, connecting-rods, eccentrics, straps, yokes, and blocks, or cross-heads, cranks, balance-wheels, and the other complications

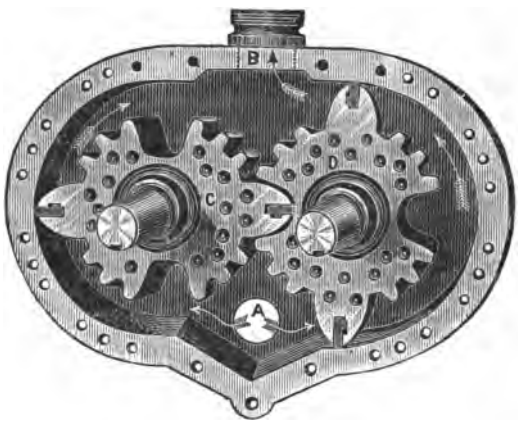


Fig. 47.

of piston engines, are entirely done away with. Many reciprocating engines have as many as from twenty to thirty moving parts.

Steadiness of Engine.

As the parts of the engine revolve rapidly, continuously, and without change of speed or direction, there is no jarring communicated by them to other

parts of the machine. On the score of steadiness, therefore, the superiority of this engine over reciprocating engines is so noticeable as to attract immediate attention.

Compactness of Engine.

The motion being circular, a much higher piston speed is permitted than is at all possible in the cylinder of a reciprocating engine of the same size. No space is required for incessant forward and backward motion of connecting parts, as in reciprocating engines.

Power of Engine.

As the engine does not have to waste from one-third to one-half its force in moving its own parts violently about, it is safe to claim for it a material increase in efficiency over reciprocating engines. It can perform effective service with very low steam pressure, from fifty to sixty pounds being all that is necessary for fire duty, while over eighty pounds is seldom, if ever, required; contrasted with which, many reciprocating engines have to use at fires as high as one hundred and twenty pounds of steam.

The Pump

is on the frame, in a line with the engine, and its construction is similar. Each cam in the pump has three long teeth instead of two, which insures a steadier motion. The packing is the same. The

cams, *G* and *H*, are fixed on steel shafts, one of which is coupled to the corresponding shaft of the engine. The action between the engine and pump is direct, the outside gears steadying the motion and equalizing the pressure. As will be seen by Fig. 48, the water enters at *E* and discharges at *F*. The water spaces

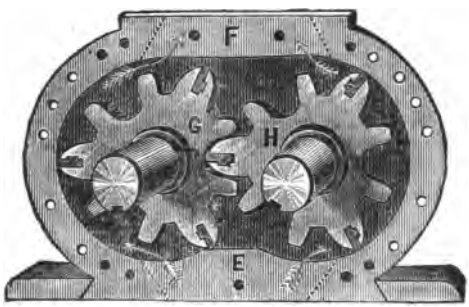


Fig. 48.

are large, allowing free passage for any foreign matter that may enter the pump; and sandy, dirty, or gritty water, that would cut a piston pump to pieces, can be worked.

Simplicity of Pump.

As in the engine, there is an entire absence of all those working parts, such as valves and other adjuncts, which cause complication, friction, and liability to derangement. Some of the reciprocating machines have in their pumps from thirty to forty delicate valves, with springs and ground surfaces, whose only office is to partly remedy the faults of the

reciprocating principle. When these valves stick, or do not seat, the efficiency of the machine is greatly compromised, and, when operating at their best, they obstruct the water in its already disturbed and intermittent passage.

Steadiness of Pump.

The motion of this pump is equable, continuous, and rotary; no blows are given to the water, which enters and leaves in one continuous flow, and no irregular motion to the stream. With the pump of a reciprocating steam fire-engine, the stroke is so rapid that the pump-barrels have not time to rapidly fill and empty, the blows and jars are communicated to the stream, causing it to waver, and to the whole machine, causing it to rock and jump about, necessitating its being "jacked up" off the springs while working, if vertical, or "chocked," if horizontal. Even this, however, does not obviate that straining and bursting of the hose and wavering of the stream, caused by the rapidly repeated blows of the reciprocating piston, nor does it do away with the chafing of the hose against the wheels or ground. This engine, on the other hand, stands perfectly still, even when running to its full capacity, and does not wear or chafe the hose.

With the same nozzle and pressure, one man can hold the discharge-pipe of this engine as easily as three can manage that of a reciprocating machine.

Reliability and Durability of Pump.

There being no valves in the pump to stick, clog, or rot, it is always ready for work; it also requires no priming. Sand, grit, leaves, sticks, saw-dust, or dirt cannot clog it; and, the pump being chambered, it cannot be cut or otherwise injured by them. The water-ways are large, direct, short, and unobstructed.

The Silsby Boiler

is made of Siemens-Martin homogeneous steel, and is of peculiar and improved construction. It is vertical, and both tubular and tubulous; *i. e.*, there is an extended heating and circulating surface of water-tubes in addition to the ordinary smoke-flues.

A is the fire-box, with water-leg. From the crown-sheet hang circulating water-tubes, C, closed at the lower ends and tightly screwed into the sheet. These tubes are inclined so as to best receive the heating action of the fire. One of them is shown detached in Fig. 49. Within each of these tubes is a light iron tube, down which the water passes after being heated by contact with the smoke-flues, D. Becoming highly heated and evaporated, the resultant steam escapes through the openings at the bottom, passes upwards through the annular space between the inner and outer tube, and becomes still further heated. Reaching the upper chamber, it is further heated and dried by the smoke-flues, D.

The boiler may be fed with cold water if desired, although special heating apparatus enables the

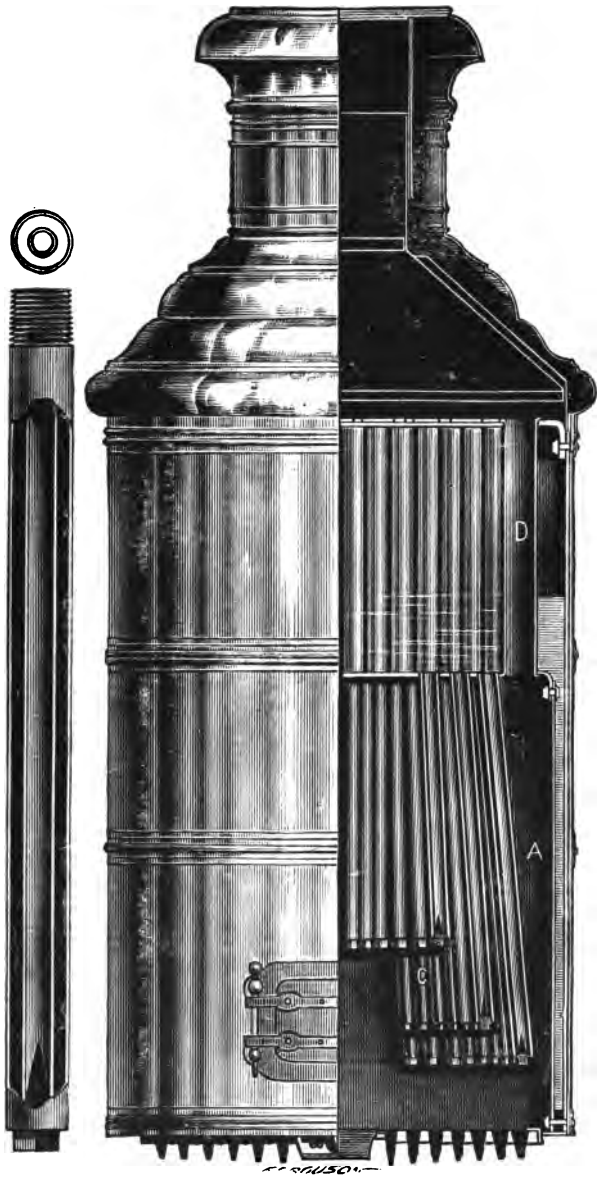


Fig. 49.—THE SILSBY BOILER. Page 186

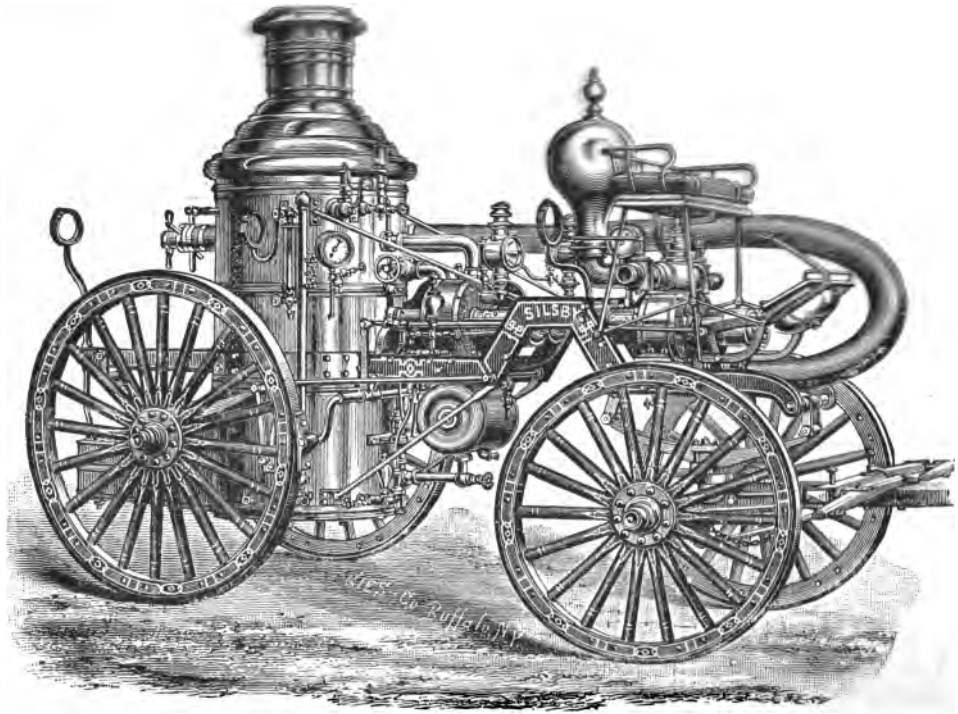


Fig. 50.—THE SILSBY STEAM FIRE-ENGINE. Page 187.

feed-water to enter the boiler from the tank at a temperature of 212°, resulting in great speed and economy in steaming. The boiler can also be fed direct from the main pump.

The water-flues can be taken out and replaced in a few minutes; and the smoke-flues, being fastened from the crown-sheet to the top-head of the boiler, are easily accessible by removing the dome, should repairs become needed, it not being necessary to tear the boiler to pieces, as is the case with some others. The boiler will raise steam from cold water in from 4 to 6 minutes; it has great steaming qualities; will burn either coal or wood; will not foam or prime, and there is no danger of its over-heating. There is a dump-grate, so that the fire can be drawn instantly, if desired.

The Silsby Steam Rotary Fire-Engine.

In 1854 the invention of the Holly Rotary pump, which became the property of the Silsby Manufacturing Company, Seneca Falls, N. Y., opened a new career for its genius, energy and capital. At that time the attention of the public was being attracted to various experiments in the construction of steam fire-engines, and Mr. Silsby, the senior member of the company, quite in opposition to the judgment of his associates, determined to enter the field of competition. In the year 1856 the first Silsby Rotary steamer was presented to the public—the first of any kind whatever having been brought out only three

years previous. Thus it will be seen that Mr. Silsby was literally one of the pioneers in the manufacture of steam fire-engines. He was also the first to produce a practical and successful steam fire-engine.

From its birth the Rotary encountered an unreasonable and unbending prejudice among machinists and engineers against the rotary system. Without test or trial the verdict was almost universally pronounced that they must necessarily prove a failure and it was therefore useless to test them. In the face of actual tests developing their superiority, prejudice often assumed the form of bigoted opposition, and it seemed almost impossible in the presence of these combined adverse elements brought about by the friends of the piston system that the Rotary should ever achieve success. But while it was a fight among giants, the Rotary proved to be the most formidable giant. All barriers have been broken down; prejudices have been conquered by the inevitable force of actual worth; twenty-five years of uninterrupted success have silenced all cavil, and to-day the Silsby Rotary is acknowledged *par excellence*, the model fire-steamer of the world. Wherever the Rotary has once obtained foot-hold and its merits have become known, it has never been successfully supplanted, and where it has been the longest in service there it is the most highly prized. (See Fig. 50.)

The struggle of the Rotary for position has been one of peculiar tenacity. Every manufacturer of a piston-engine was interested in the crushing of this

new and promising candidate for popular favor, and in all competitive trials the conditions were made as uniformly unfavorable as possible for the Rotary. But these devices were unavailing. It was always found that the Rotary would take water where the piston could not, that when the throttle was opened the Rotary was ready to go to work, and that there she would stand and continue to work as long as human endurance could supply her with fuel for motive power. Some of the most wonderful exhibitions of hydraulic power shown by the Silsby Rotary Steam Fire-Engine have excited world-wide comment. At Buffalo, one of the Silsby steamers, connected with the fire department, was in actual service working under steam for three weeks. At Cape May, N. J., when the water-works gave out, a Rotary steamer worked twenty-three days and nights, supplying the whole city with water. The same was the case at Burlington, Iowa, where for several days a steamer forced water for the city through over nineteen miles of pipe. At Duluth, a Silsby steamer worked continuously for about a day and a half with the thermometer at 35 degrees below zero. These are but a fragment in the mass of testimony to the reliability and durability of the Rotary which has forced a reluctant approval from its most sceptical opponents, and elevated it to the prominence it now occupies among appliances for the extinguishment of fires.

The improvements made in the Rotary during these twenty-five years are not alone in the external

appearances of the machine, although these are striking. Constant advance in the capacity of the engine and a simplifying of its details are the two ends chiefly sought in progressing the Rotary. To these ends much study and genius are applied. In a short period recently five patents upon the Rotary steam fire-engine have been issued to the Silsby Manufacturing Company. The combined result of these improvements is distinctly observable in the tests recently made of new machines from the "Island Works" delivered at various places. As an example we note a few among recent tests recorded:

A second size Silsby recently tested at Malden, Mass., threw a 1½ inch stream 270 feet, and a 1¼ stream 300 feet, drafting the water 15 feet perpendicularly.

At Oswego, a second size threw a 1¼ stream through 100 feet of hose with a smooth nozzle 291 feet, and a 1⅛ stream through 1,000 feet of hose 227 feet.

A second size, at Brockton, Mass., recently threw 287 feet, through 100 feet of hose, with a 1½ inch nozzle, as the report says, "without any extra effort," and on the same day, with a 1⅛ nozzle, through 1,000 feet of hose, put a stream 228 feet.

At Selma, Ala., a third size threw a 1¼ stream 305 feet through 100 feet of hose.

At Shamokin, Pa., a fourth size with a 1⅛ nozzle and 100 feet of hose, threw 307½ feet, and on the same day threw perpendicularly five feet above the

cross on the Catholic church, 212 feet above the sidewalk.

More recently, a test of the new sixth size (the smallest made) was had at Moravia, N. Y., where a stream of 260 feet was thrown through a 1 inch smooth nozzle, and a stream was thrown perpendicularly some thirty or forty feet over the M. E. church spire 126 feet high—this with a 1 inch smooth nozzle through 500 feet of hose.

A first size Silsby recently tested at Buffalo, threw a $1\frac{1}{2}$ inch stream 325 feet.

At Richmond, Va., a third size threw a $1\frac{1}{2}$ inch stream 300 feet. At Troy, Ala., a fifth size threw a $1\frac{1}{8}$ inch stream through 1,000 feet of hose, 210 feet, while at Denver, Col., a fourth size threw a $1\frac{1}{8}$ stream 315 feet.

These remarkable illustrations of the power and progress of the Silsby Rotary illustrate also the growth of the demand for them through the country.

Rules for the Management of Steam Fire-Engines.

The Amoskeag Company give the following rules for the management of steam fire-engines:

1. In laying fuel in the fire-box, first lay plenty of shavings, then light, dry kindling wood, filling the furnace full, which in most cases will give steam enough by the time the engine arrives at a fire to commence work, provided the fire is lighted when leaving the house, which, as a general rule, is advisable.

2. If coal is used, be careful to keep a thin fire, and not clog it. Use the coal in as large lumps as possible, and do not break it up unnecessarily in the furnace. The best coal for this purpose is a clean Cannel, in lumps, free from dirt and dust.

3. Be careful not to let so much fire collect under the engine as to burn the wheels. When working for a long time at fires there is some danger of doing so.

4. The Amoskeag boiler is an upright, tubular boiler, with a submerged smoke-box and fire-box surrounded with water. When the engine is running, the water in the boiler should be carried so as to stand at the third gauge-cock, which is placed near the top of the tubes, and it should never be carried below the center of the tubes, at which point the first gauge-cock is located.

5. Avoid using an unnecessary amount of steam. The tendency is to use more than is required. From sixty to eighty pounds is as much as will generally be required to do good fire duty.

6. The engine has two suitable feed-pumps for supplying the boiler with water. One of these pumps should be worked nearly all the time, in order to keep the water in the boiler at the proper height, and to preserve an even pressure of steam.

7. If brackish water is used for supplying the boiler, or if the boiler becomes foul from long use without being blown off, it is likely to foam or prime. If foaming occurs while the engine is working at a fire, it may be prevented or diminished by opening

the surface blow-off cock, which is located between the third and fourth gauge-cocks, and blowing off from the surface of the water the scum and oily matter which usually causes foaming. In this way the difficulty can be generally prevented without any serious interruption in the working of the engine. While doing this the water in the boiler should be carried as high as the surface blow-off cock. After the engine is returned to the house, the water should be blown entirely out of the boiler through the blow-off cock near the bottom of the boiler, with a steam pressure of about twenty pounds, and the boiler re-filled with fresh water. This process may be repeated until the boiler becomes clean.

8. The pump upon the Amoskeag engine is a vertical double-acting pump, with the cylinder surrounded by a circular chamber, divided vertically outside the cylinder, so as to answer both for the suction and discharge chambers of the pump. It has a separate valve-plate at the top and bottom of the pump, carrying both the suction and discharge valves, the suction-valve upon one side of the plate, and the discharge-valve upon the other. Each of these valve-plates can be reached by taking off the top and bottom of the pump, which is so constructed as to be readily removed. The discharge and suction parts of the water-chamber surrounding the cylinder are connected by a valve in the vertical partition, which is called a relief-valve.

9. With a single long line of hose, it may be

necessary to open the relief-valve a little, but at all other times be particular to have it closed, except when desired to feed the boiler without forcing any water through the hose.

10. In the smoke-pipe, directly over the upper flue-sheet, a valve is placed, which is called the variable exhaust valve. By operating this valve, the size of the aperture for the escape of the steam from the steam-cylinder is increased or diminished, thus regulating the draft of the chimney and the heat of the fire. This valve should be closed when the engine is started, until a fair working pressure of steam is obtained, after which it may be opened.

11. Care should be taken to have the suction-hose and its connections air-tight.

12. Open the discharge-gate and cylinder drain-cock before starting the engine.

13. Don't let the flues of the boiler get filled up.

14. Be particular to take the engine off the springs before you work it, and to place it on the springs again when done working.

15. With a long line of hose on, be particular to open the throttle gradually. If it is opened too suddenly, it is liable to burst the hose.

16. The pumps of the engine should be examined at least once in six months, to see that the valves and all the parts are in good condition. The pump-valves should have a lift of about three-eighths of an inch, and the suction-valves the same lift.

17. The inside of the steam-cylinders and the

steam-valves should be oiled or tallowed always after the engine has worked at a fire, and as often as may be necessary to keep them well lubricated; and all the parts of the engine, where liable to friction, should be kept well oiled. Be particular to use an abundance of oil on the "link-block," where there is more friction than in any other part.

18. The running-gear, and every part of the engine liable to disarrangement or accident, should be thoroughly examined every time after the engine has been out of the house, whether it has been worked at a fire or not.

19. Whenever the engine is repaired the engineer should try to help do it himself, as, by so doing, he gets a familiarity with it that he can in no other way obtain.

CHAPTER VI.

STANDARD AMERICAN STEAM PUMPS.

DIRECT-ACTING steam pumps are so generally used now, that we are frequently called on to answer many questions relating to their methods of working, and especially as to the manner in which the steam valve or valves are moved and operated, in order to change direction at each end of the stroke. We therefore intend in this chapter to describe the various valve motions for direct-acting pumps now commonly used, so that engineers can familiarize themselves with the action without taking them apart.

The Davidson Steam Pump.

Among the leading standard builders are the Davidson Steam Pump Co. Their ingenious valve-gear we illustrate herewith (Fig. 50½), showing all the parts and passages in connection therewith.

The peculiarity of the steam end of this pump is, that unlike other direct-acting steam pumps, it has only one valve in the steam chest. This may be properly called a compound slide valve with cylindrical face. (See Figs. 51, 52, 53.) It performs two

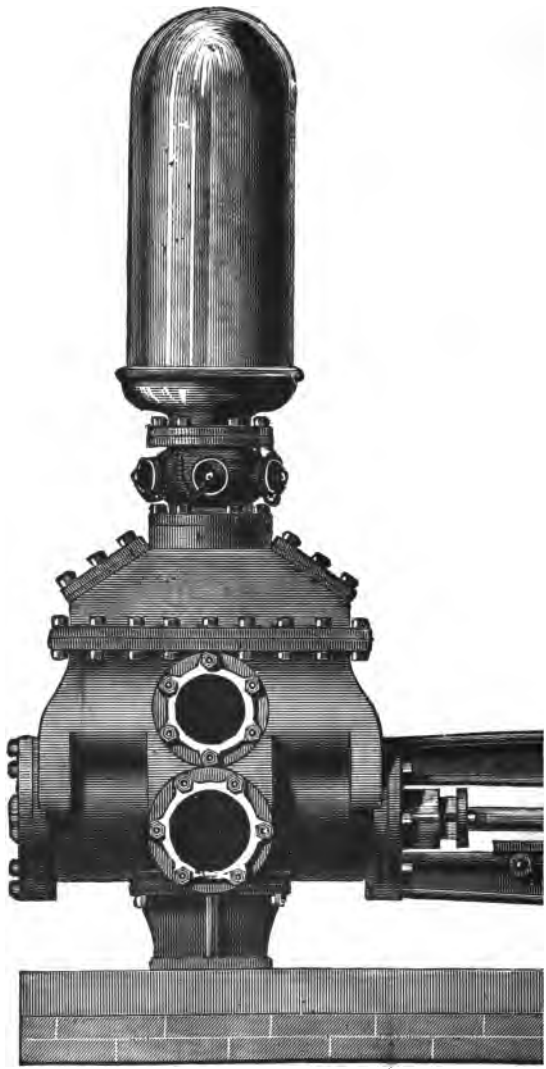
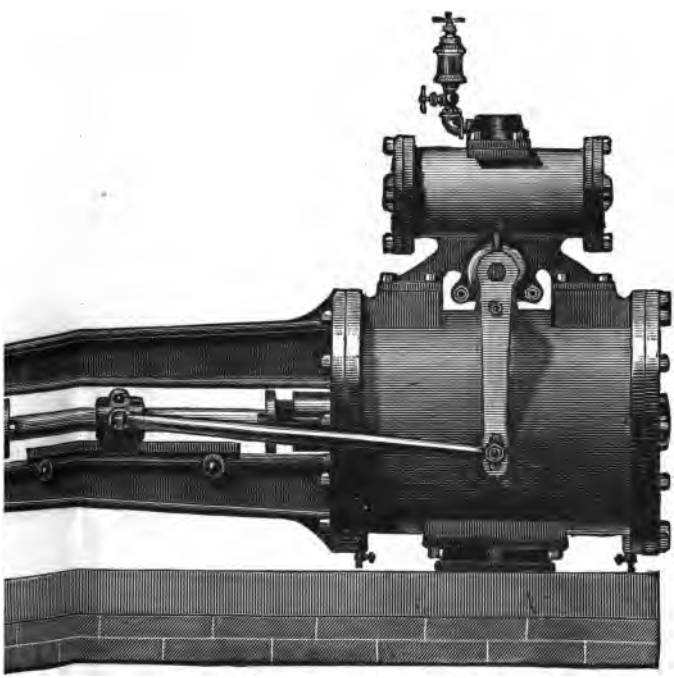


Fig. 50½.—The Davi



DAVIDSON STEAM PUMP. Page 196.

duties, that of the ordinary slide valve and of the auxiliary valve combined. Its duty as a slide valve is, of course, to reciprocate across the steam ports *c c*, to admit steam alternately to the two ends of the steam cylinder, and as an auxiliary valve it is oscillated so as to open and close the steam ports *a a*, that lead to the ends of the steam chest.

The steam chest is cylindrical and bored out to make a face for the slide valve *B*, and to receive the pistons that assist in operating the valve. The pis-

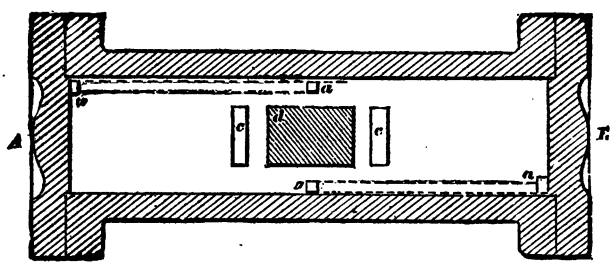


Fig. 51.

tons are connected together, sufficient space being allowed between them for the valve and steam ports, and they are also connected to the slide valve, all working in the same plane and being of the same diameter, thus insuring evenness of wear and readiness of access for adjustment, repairs, etc. An examination of the valve will at once suggest the impossibility of its getting out of order, becoming deranged or wearing out within the life of any other portion of the pump. The valve is oscillated by an oblique cam, *h*, connected with the valve by a steel pin passing through the

valve into the exhaust port, in which the cam is

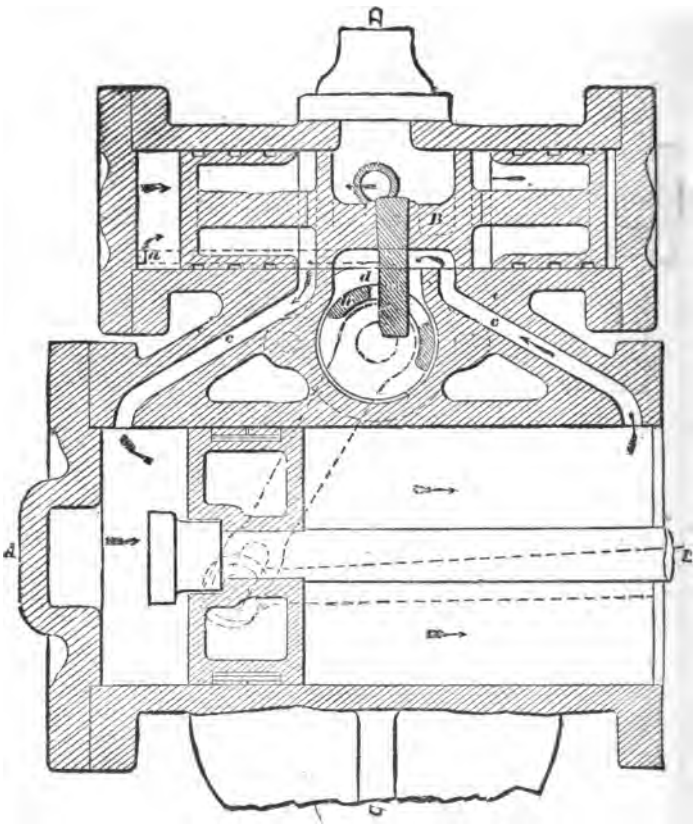


Fig. 52.

placed. The moving of the valve does not depend entirely upon the steam admitted to the end of the

valve piston, for should that not be quick enough to

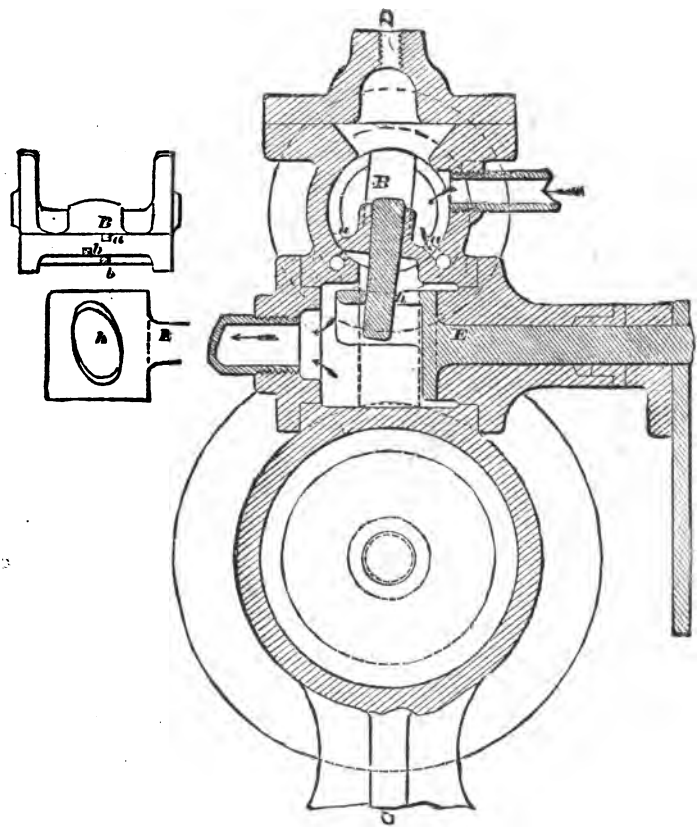


Fig. 53.

operate on the valve, with the pump under a high rate of speed, the cam is so constructed that it will

carry the valve mechanically, and thus prevent the piston from striking the cylinder heads in any case.

The valve ports are so constructed that the water from condensation in steam pipes, etc., is carried off at each stroke through the main exhaust-port, and thus it will be seen that the valve is *always* free to move as soon as the steam is admitted. This valve motion and its adjustment enables these pumps to run with the same if not even less piston clearance than the ordinary steam engine. For instance, a No. 8 pump is set to run with $\frac{3}{16}''$ piston clearance, thus saving a vast amount of steam. The steamports are, it is said, fifty per cent. larger than any other pump made, insuring a high initial steam pressure.

The motion of the valve, as it anticipates the return stroke, is slow, owing to the form of the cam, so that the load may be moved from a point of rest without shock. This allows the pump to be run at a high piston speed without disturbance to the machine or its pipe attachments. The oblique cam is a steel forging, hardened on its working-face, while the pin entering the groove is also of steel hardened.

The cam first gives oscillating motion, opening the auxiliary ports for throwing the valve in a longitudinal direction; the first motion is about $\frac{3}{8}$ of an inch, while the valve moves in a straight plane, just one-eighth the whole movement of the pump-piston. The pump will always start from any point.

It can also be run as slow as any of the other pumps, and as the time required to overcome the

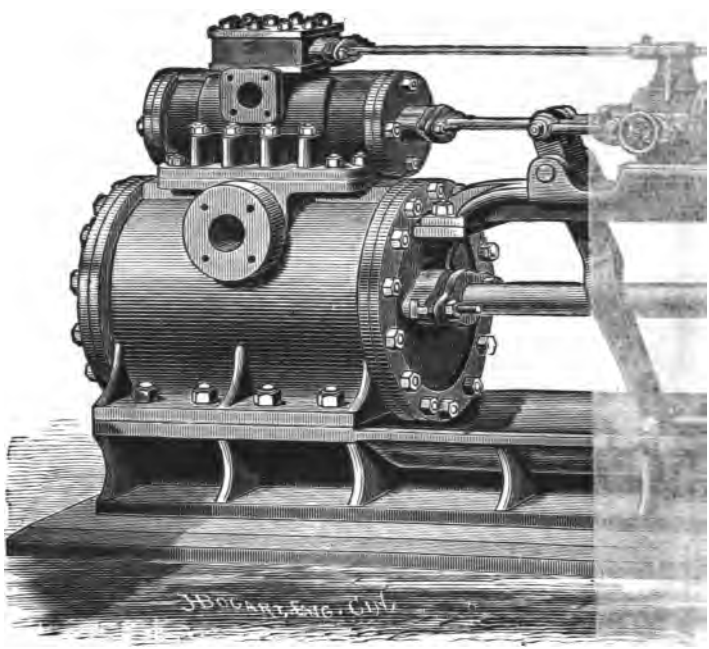
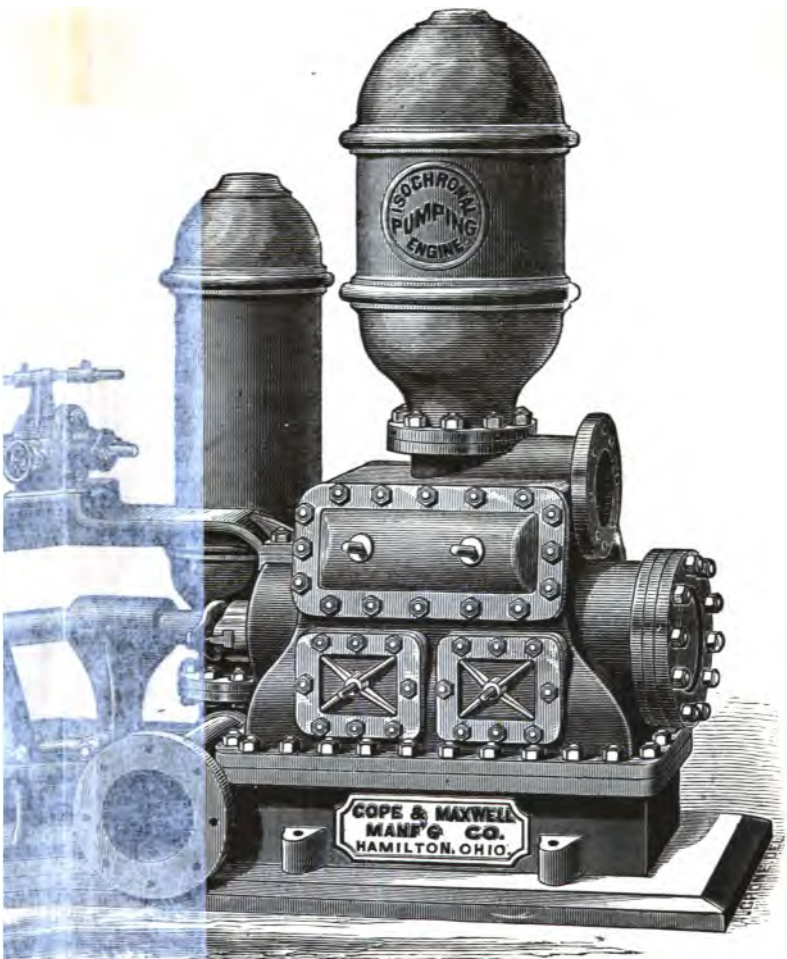


Fig. 54.—The Isochronal Pumping



(*Perspective View*). **Page 201.**

inertia of the valve and plunger remains constant, while the distance moved by the pump piston varies with the velocity, it follows that the length of the stroke remains constant in this pump. It is perfectly noiseless.

The Isochronal Pumping Engine.

The principle of operation of the ordinary governor is well understood in connection with ordinary steam engines, and those informed upon the subject will readily appreciate the difficulty, if not impossibilities, of applying such governors to steam-pumping engines which have no revolving parts.

In pumping engines, nice regulation is of the utmost importance on account of the damage which may result from irregular action. "Isochronal" means "equal spaces in equal times," and the isochronal pumping engine herewith illustrated possesses the peculiar property of maintaining a uniform rate of piston travel under varying conditions of power and resistance; in short, it is perfectly self-governing. Fig. 54 is from an engine having a steam cylinder two feet in diameter and a pump one foot in diameter. The stroke is two feet. The machine is adapted to water work purposes, and any similar work where a uniform motion is desired under all variations of conditions. The isochronal pumping engine is its own engineer in this respect.

The means employed for rendering this pumping engine isochronal are so simple, so perfect, and so interesting in principle, that we have thought the

matter deserving such a description as will render it better understood among those interested.

In general arrangement (see Fig. 55) this pumping engine does not materially differ from the ordinary steam pumping engine of similar type; that is to say, the main valve is moved by a small auxiliary engine whose valve is moved by a lever actuated by the main piston rod. In the illustration, the small upper rod is the stem of the valve of the auxiliary engine, and the lever upon the main piston rod actuates this stem through the tappet collars *e*, the intervening devices in the neighborhood having no effect upon this function of the lever.

In addition to moving the small valve, the lever reciprocates a short cylinder H, having a piston, a channel from end to end, and a regulating cock I, for altering the capacity of the channel. This cylinder is filled with oil, and it will be readily understood that if the piston within it be stationary, the oil will be transferred from end to end of the cylinder, as the cylinder reciprocates. The oil in being transferred passes through the channel referred to. It should now be understood that liquid will pass through any sized opening, if it is allowed time enough, but if an attempt be made to force it through faster, it will offer great resistance, and will react on the urging medium. This principle is involved in the regulating of the motion of this engine, and is utilized by causing any unusual reaction in the oil cylinder to effect a change in position of the main

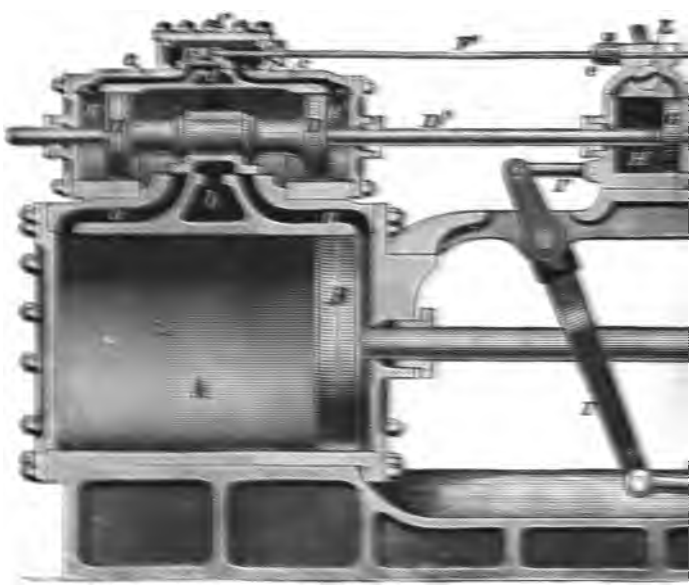


Fig. 75.—The Isothermal Pumping Eng

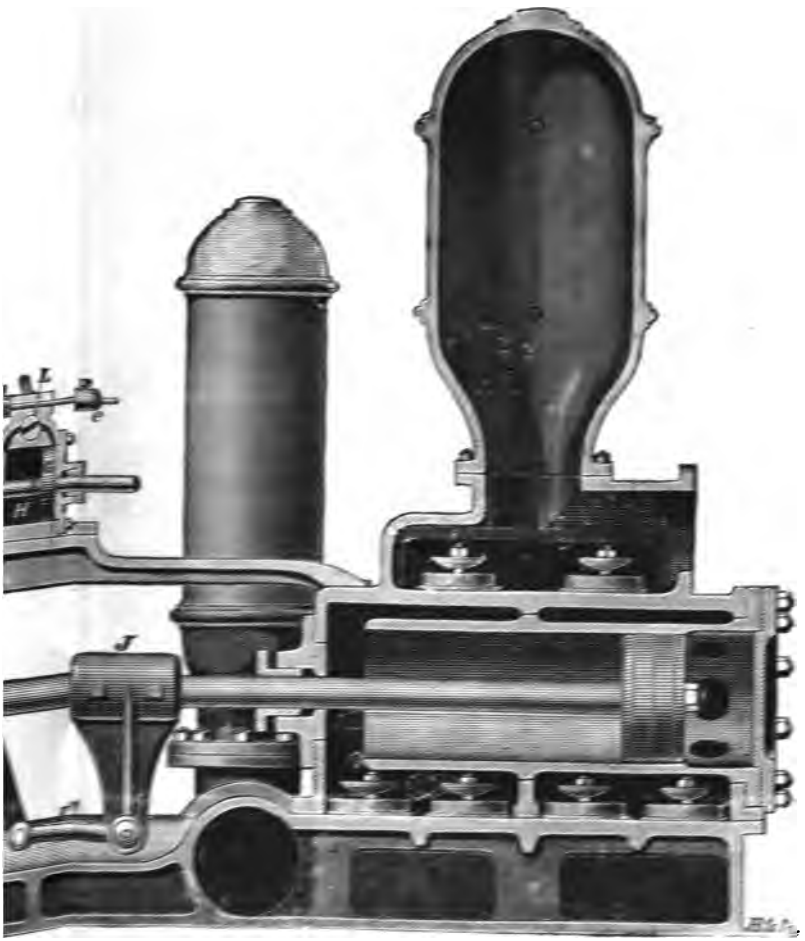


Fig. [illegible] 'Longitudinal Vertical Section.' Page 202.

valve of the engine. Let us suppose that the main has opened one port; that the valve is held in that open position by the pressure of steam upon the auxiliary piston; that the auxiliary piston and the oil piston are, as is the case, united by a rod; and that the channel cock is so set that the oil may shift every ten seconds, and produce just reaction enough to balance the pressure of steam upon the auxiliary piston. The auxiliary piston tends to keep the main valve open, and the reaction of the oil tends to shut the main valve. The forces balance and, of course, the main valve remains open. But suppose the resistance of the pump to be suddenly decreased, by the bursting of a main, for instance, then the main piston would be disposed to suddenly increase in velocity and, if uncontrolled, to "race."

In this case it will be seen that the oil would be asked to pass through its channel at a quickened rate, a proceeding which, by law, it objects to, and it indicates that objection by an increased reaction on the oil piston, which is thus caused to preponderate in power over the steam pressure on the auxiliary piston and to effect a proper closure of the main valve. An increase in pump-resistance tends to slow the motion of the main piston and of the oil cylinder, to reduce the reaction and thus allow the auxiliary piston to effect a proper opening of the main valve. In short, if the main piston by increased motion tends to force the oil through the channel in less than ten seconds' time, the oil piston pushes the main

valve into a more closed position, and checks the tendency; and if the main piston by lagging tends to give the oil more than ten seconds' time to shift, then the oil reduces its reactive force, and allows the auxiliary piston to open the main valve wider and check the lagging tendencies. This rigid exactitude goes on through each stroke, and through every inch of every stroke, and maintains that proper amount of valve-opening which is required for a stroke in ten seconds, or six strokes per minute. The channel-cock being once set for any desired rate of motion, that motion will be constantly maintained spite of any or all changes in power or load. So delicate is the action of the oil-cylinder, that if the discharge-pipe be opened wide to the air, and thus present no resistance, the main valve will barely open and the motion will be at the rate for which the channel-cock was set; and if the discharge be suddenly, almost totally closed—thus applying the maximum resistance to the pump—the main valve will instantly give more port, and suiting itself to its new duty maintain the same piston motion as before.

The oil-cylinder is shorter than its stroke, and just before the end of the stroke it moves the main valve in a positive manner, and closes the main exhaust, thus forming an absolute cushion for the main piston. When a stroke is complete the tappets open the small valve, and allow steam to act on the other end of auxiliary piston, and move the main valve for a new stroke, but in doing this the auxiliary piston is re-

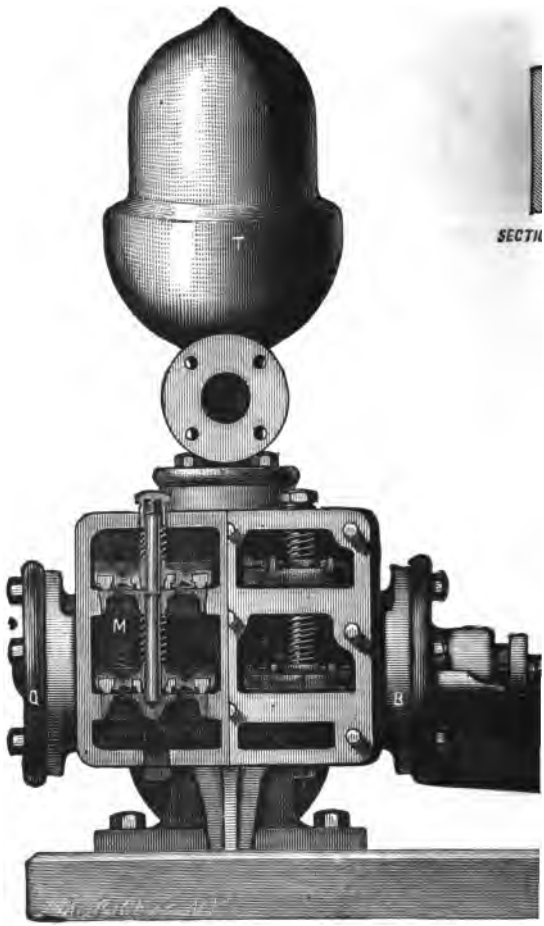
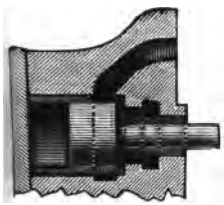
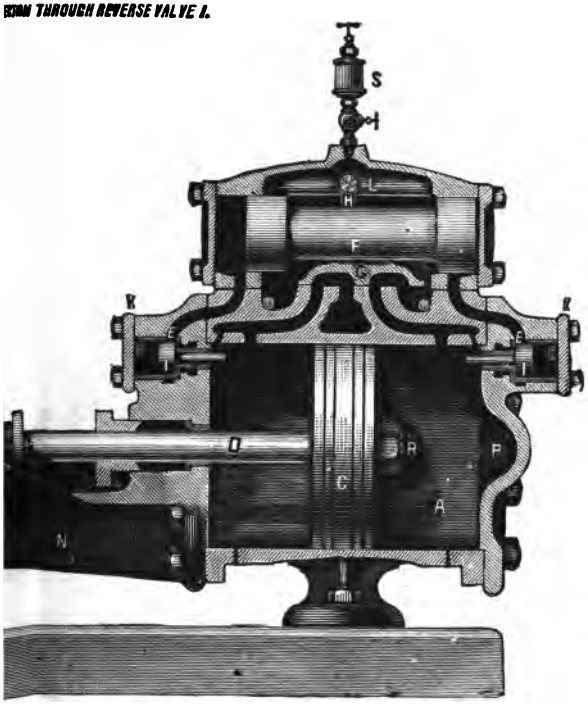


Fig. 56.—The Cameron Steam I



EAM THROUGH REVERSE VALVE L.



EAM PUMP (*Sectional View*). **Page 205.**

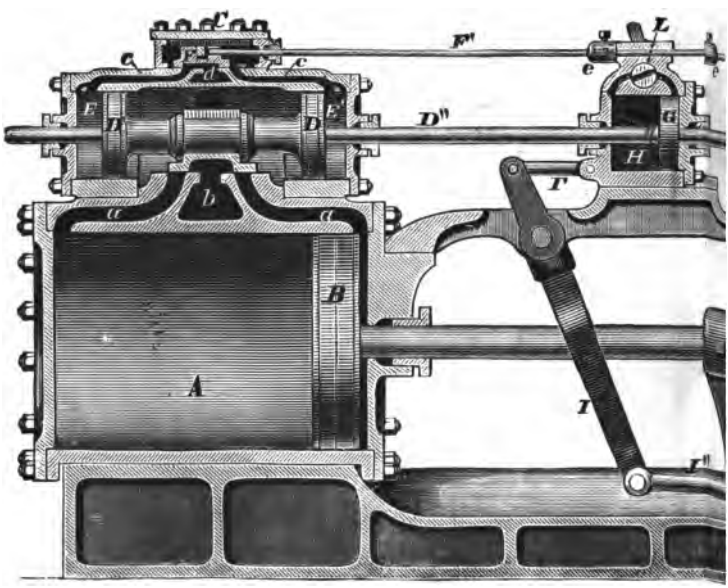
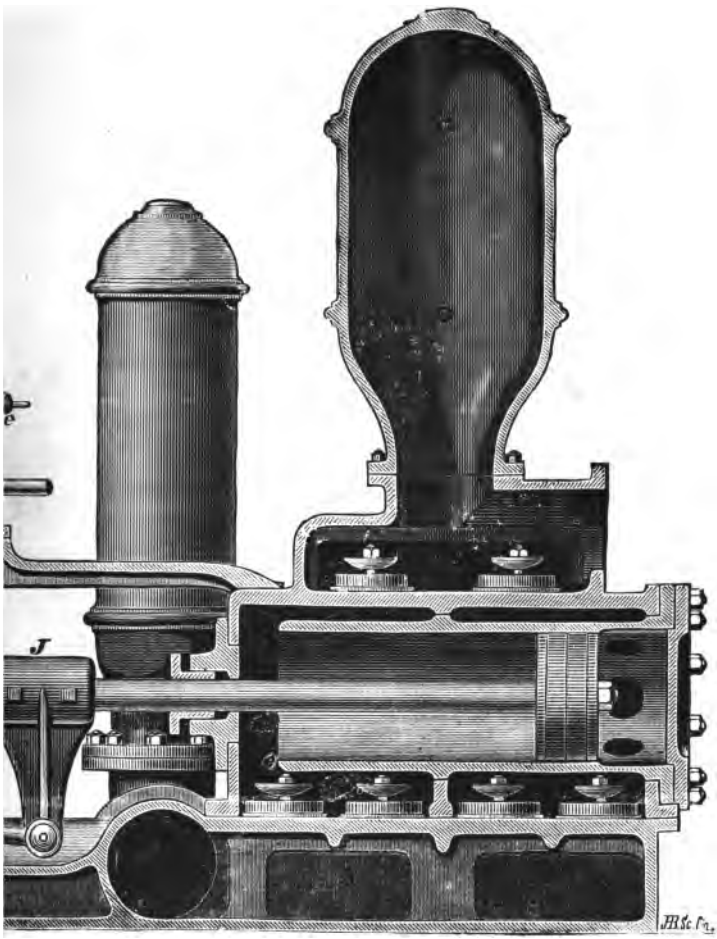


Fig. 55.—The Isochronal Pumping Engine



IE (*Longitudinal Vertical Section*). **Page 202.**

and slide valve, G, and the motion of the piston, C, is instantly reversed. The same operation repeated at each stroke makes the motion continuous. The reversing valves, I, I, are closed by a pressure of steam on their larger ends, conveyed by an unseen passage direct from the steam chest.

Directions.

When a pump is first connected, remove the bonnets, K, K, and valves, I, I, and blow steam through to remove any dirt or chips that may have lodged in the pipes; then clean and replace them.

The LONDON "ENGINEERING" says:—This is the simplest of the class of steam pumps with steam moved valves which has come under our notice. The action is certain at all speeds, and when working at full speed, and with 100 pounds pressure in the air vessel, the suction hose may be suddenly lifted out of the water without the pistons striking the cylinder covers (a severe test). The parts are so accessible that, although still hot with steam, and just after it had been working, we had it to pieces in hardly more than a minute.

Useful Information for Engineers and Steam User in Regard to Steam Pumps.

In ordering a pump it is for the interest of the purchaser to fully inform the builder on the following questions:

1st. For what purpose is the pump to be used? What is the average pressure of steam?

2d. What is the liquid to be pumped? and is it hot or cold, clear or gritty, fresh, salt or acidulous?

3d. What is the maximum quantity to be pumped per hour?

4th. To what height is the liquid to be lifted by suction, also the height of discharge? What are the length and diameter of the suction and discharge pipes, and the number of elbows or turns?

Directions for Setting and Connecting Pumps.

Never use pipes too small in diameter. In long pipes this should be increased to allow for increased friction, especially in suction pipes.

Use as few bends and valves as possible, and run every pipe in as direct a line as practicable, and where convenient use full round bends rather than elbows. Valves, returns and elbows increase friction more rapidly than length of pipe, and no pump can work satisfactorily that does not have a full supply of water.

Pumps should always be drained in cold weather, as freezing of water in pipes or cylinders is sure to burst them. Engineers should therefore be careful and open the drip plugs and cocks—which are provided on all pumps for draining them.

Water at high temperature cannot be raised any considerable distance by suction, as the vapor discharged from the water so heated follows the receding

pistons of the pump and resists the entrance of the water; consequently to pump hot water always place the supply above the pump so that it will be supplied from a head.

A vacuum chamber upon the suction pipe, close to the pump, is always an advantage, and on long lines of pipe or on pumps running at a high rate of speed, is absolutely necessary. Their utility consists in causing a steady and uniform flow of the fluid through the suction pipe, and thus preventing "pounding" or water hammering, which (without one) is always incident to long suctions.

Useful Information.

A gallon of fresh water contains 231 cubic inches, and weighs 8⅓ pounds (U. S. Standard).

A cubic foot of water contains 7½ gallons, or 1,728 inches, and weighs 62½ pounds.

The friction of water in pipes is as the square of the velocity. Doubling the diameter of a pipe increases its capacity four times.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by 0.434. Approximately we generally call every foot elevation equal to ½ pound pressure per inch; this allows for ordinary friction.

In calculating horse-power of steam boilers, consider for

Tubular boilers, 15 square feet of heating surface

equivalent to one horse-power; flue boilers, 12 square feet of heating surface equivalent to one horse-power; cylinder boilers, 10 square feet of heating surface equivalent to one horse-power.

Each nominal horse-power of boilers requires 1 cubic foot of feed water per hour.

One square foot of grate will consume, on an average, 12 pounds of coal per hour.

Consumption of fuel averages 7½ pounds of coal, or 15 pounds of dry pine wood, for every cubic foot of water evaporated.

Ordinary speed to run steam pumps—when the duty is not heavy—is 100 feet of piston travel per minute.

To find the quantity of water elevated in one minute, running at 100 feet of piston travel per minute. Square the diameter of water cylinders in inches and multiply by 4. Example: Capacity of a 5-inch pump is desired. The square of the diameter (5 inches) is 25, which multiplied by 4 gives 100, which is gallons per minute (approximately).

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston travel being the speed), divide the number of gallons by 4, then extract the square root, and the product will be the diameter in inches.

To find the capacity of a cylinder in gallons. Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical con-

tents of a gallon in inches), and product is the capacity in gallons.

The area of the steam piston, multiplied by the steam pressure, gives the total amount of pressure that can be exerted. The area of the water piston, multiplied by the pressure of water per square inch, gives the resistance. A margin must be made between the power and the resistance to move the pistons at the required speed—say 50 per cent.

Wright's Patent Double-Acting Bucket Plunger Steam Pump,

As improved by the Valley Machine Co., Easthampton, Mass. We give herewith a sectional view (Fig. 57) of the pump, from which the operation will be readily understood. (A) is the steam valve, and (B) the steam cylinder; (C) is the upper and small porton, and (D) the lower and large portion of the plunger connected thereto. (E) is the water cylinder, (F) the suction valve, and (G) the discharge valve. (I) is a passage in the upper end of the water cylinder, through which water is taken in on the down and discharged on the up stroke. (J) is the vacuum, and (K) the air chamber.

The water valves are simply circular pieces of metal or rubber, rising on a stem which is fastened to the valve seats. Thus, should a valve fail, a circular piece of leather or rubber packing would answer temporarily until something better could be obtained.

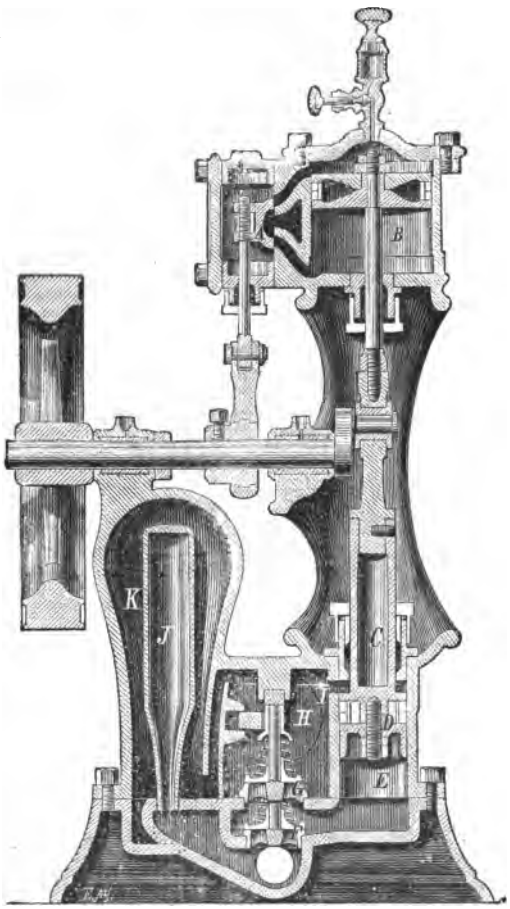


Fig. 57.—Wright's Double-Acting Bucket Plunger Steam Pump. (*Sectional View.*)

The packing rings in the water plunger are made of gun metal, the inside ring being made thinnest at

the cut, thus giving more elasticity with less friction.

Fibrous packing can be used instead of the rings, if preferred, or a solid bronze metal end can be used instead of either.

The water valves can be removed by simply unscrewing two nuts, and withdrawing the wedge that rests on the discharge valve stem, the suction valves being directly under the discharge valves in the base of the pump. Rubber valves can be substituted for metal, or *vice versa*, without a change of valve seats. The steam valve is properly "set," and the eccentric *keyed* on to the shaft. Best quality steel is used for valve stems and piston rods. Genuine Babbitt mixture in the shaft bearings.

The Dean Steam Pump.

Fig. 58 represents a new pump, with steam cylinder 18 inches in diameter; water cylinder, 12 inches in diameter; stroke, 24 inches; suction pipe, 10 inches, and discharge pipe, 8 inches. The pipe connections can be made from either side of the pump, as the openings on both sides are the same. The water passages are equal to the area of the suction pipe. There are eight rubber valves, each eight inches in diameter, which can be examined or taken out by removing the hand hold plates.

The steam valve arrangement is a new and simple feature. The piston rod carries a projecting roller which moves between the flanges of the rocking cam. When the main piston approaches the limit of its

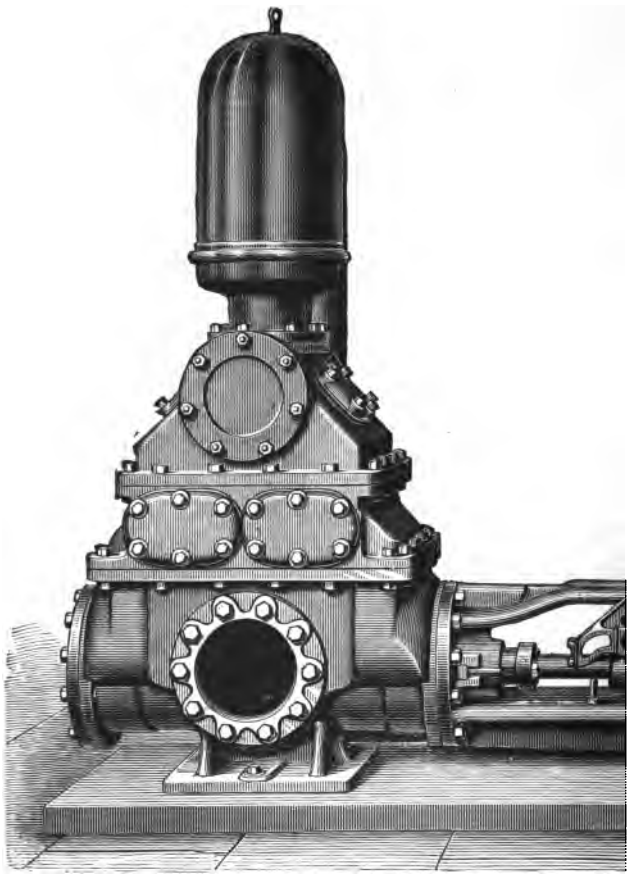
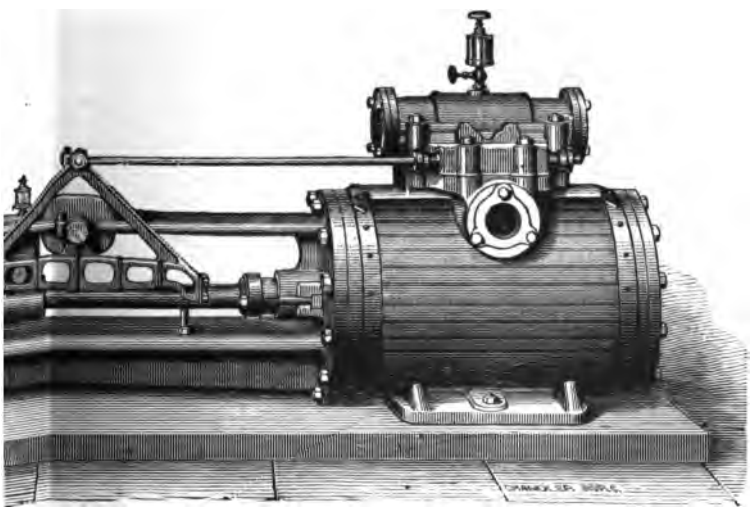


Fig. 58.—THE DEAN



NEW STEAM PUMP.—Page 212.

stroke, the roller passes between the curved flanges near the end of the rocking cam, causing it to swing and move the auxiliary steam valve, reversing the motion of the main piston. As the roller starts on the return stroke, it rocks the cam back to its first position, and brings the auxiliary valve on its center or to mid-stroke. The object of giving this motion to the auxiliary valve is to keep its steam ports closed, except during the instant the motion of the main piston is being reversed, and thus prevent loss of steam in the steam chest in case the chest piston becomes worn and leaky. Nearly all direct acting steam pumps, in time, will leak steam into the exhaust pipe, in consequence of the wearing of the chest piston. The cutting action of the steam "blowing through" greatly increases the leak.

In this pump the chest piston is plain, without steam ports of any kind. It is of little consequence whether the chest piston is leaky or not, there being no place for the steam to waste by "blowing through," as the cam motion brings the auxiliary valve to its mid stroke, keeping the passages leading to the chest closed, except during the instant the main piston is being reversed.

These pumps are made in twelve sizes, from 3-inch to 20-inch steam cylinders, and from $1\frac{3}{4}$ inch to 14-inch water cylinders.

In action this pump is smooth and virtually noiseless. It is capable of being worked at a high speed without increasing danger of injury. It is manufac-

tured by Dean Brothers' Steam Pump Works, Indianapolis, Ind.

The Dayton Cam Pump.

Fig. 59 represents an improved direct and double acting steam piston pump, which, it is claimed, is absolutely positive in its action, simple in construction, and economical in the use of steam. The principal feature is the mode of working the steam valve by

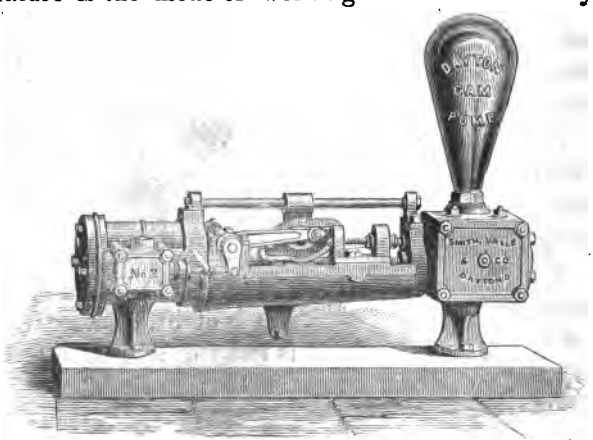


Fig. 59.—The Dayton Cam Pump.

means of a cam bolted on the piston rod and moving with it. By the shape of this cam the stroke is rendered slower at each end, thereby giving time for the water cylinder to fill. A full stream is thus insured, and the pump is prevented from cushioning against the water when the cylinder is but half filled. The arrangement is such that the valve cannot be thrown into such a position as to shut off steam and stop

the pump. The operation of the mechanism needs no further description, as the reader will readily understand the adaptation of the various parts to each other from an inspection of the annexed illustration. It will be seen that there are no dead centers, and that the action is absolutely positive. The arrangement of the cam movement, in connection with the piston, causes the water valves to lift and to set easily and without jar, thereby saving the wear and tear of valves and seats. The maximum of speed is attained when the valves are lifted and the water is flowing.

The manufacturers, in enumerating the various advantages of the apparatus, point out especially the simplicity of its construction, strong and durable material being used, and the various parts so constructed as to be readily accessible. There are no small, intricate steam passages to fill up with dirt and grease, and the water valve chambers may be easily opened to reach the valves. The steam valve, being of the plain slide description, is also not liable to become out of order.

By the greatly increased use of steam power within the last few years, it has become indispensable that some way be found for keeping the water in boilers at a constant and uniform height, and without variation. For this purpose hundreds of inventions of steam pumps, injectors and devices of different kinds, have come before the public, many of them of value, but still having defects that ought to be over-

come to give assurance of perfect safety from explosions, arising from low water and the sudden injection of water at such times. Economy of fuel has also become a most important consideration in the use of steam power, but has, up to a certain point, been unattainable from the impossibility of pumping hot water. It is claimed that all of these defects of feeding boilers, and also the requirements of a good boiler feeder, have been carefully studied and experimented upon, and the result is the presentation to the manufacturing public, and to all parties using steam, the Dayton cam pump as one of the most economical, durable and effective boiler feeders in the market. Especially so is this in regard to economy and positiveness of motion, which is absolutely necessary to pumping hot water successfully. The cam pumps are said to feed water into boilers at a temperature of 250° F., and in some instances to feed water at a temperature of from 212° to 225° F. The reason of the ability of the Dayton cam pump to perform this difficult work is its peculiar movement attained by the cam motion, causing the water valves to commence closing before the stroke is completed, and being absolutely closed at the commencement of the return stroke.

These pumps, which have been in use for some years, have, it is said, proved to be thoroughly reliable, and, owing to simplicity of construction and durability, have given general satisfaction. They are made for and adapted to all the various duties of a

first-class steam pump; are manufactured especially with a view to economy in use of steam—do not require skillful attendance, nor is there anything about them that an ordinary mechanic cannot keep in order and repair. The designs of these pumps are to have them equal, if not superior, to all others; also to combine strength, simplicity and durability. Messrs. Smith, Vaile & Co., Dayton, Ohio, are the manufacturers.

A simple glance at Figs. 60 and 61 will show that the pump is built in a strong and symmetrical manner. In practice we have never been able to detect the slightest vibration in the parts of the machine as related to each other. And as for material, it is strictly first-class. The motion is positive, because it is controlled by a continuous cam, and there is no sticking point or dead center for the same reason.

There is no steam-valve simpler than the old and well-known plain slide, or D-valve, covering two steam ports and one exhaust port. This simple construction must impress every one with favor who has had occasion to use a pump. As for the valve connections, they consist of a simple bell crank lever.

The engineer will readily see from the engravings or from the pump itself the free and liberal ports and passages in both water and steam ends. The feature is of so much practical value that it will be appreciated by all engineers.

The water valve-box, in two distinct compartments, is as plain and simple as it is possible to

construct it, and access is had with the most perfect freedom; besides, it has the additional valuable feature that by simply removing the two retaining pins (which may be seen in the sectional elevation passing through the valves and the top of the water-box), all the valves and seats can be readily withdrawn.

The pump is capable of pumping not only hot fluids that have attained the boiling point, but will also pump boiling water under pressure, and, since the temperature of water increases with the pressure, it is evident that it pumps water above the boiling point of 212 degrees. The reason for this is that the piston stops at each end of the stroke a sufficient length of time to allow the valves to seat quietly; and, after having become seated, there is no chance to wedge them up. So perfectly is this motion performed by the cam pump, that it is enabled to pump water under pressure indicating upon the thermometer 260 to 273 degrees, which equals 20 and 30 pounds pressure per square inch. This invaluable feature in the cam pump fits it eminently for pumping the water of condensation from all manner of heating apparatus, not only increasing the rapidity of circulation and the effective heating capacity, but also greatly economizing in fuel.

The following extract from that excellent work on steam boilers, by W. M. Barr, M. E., will make clear the construction of the pumps, as shown in Figs. 60 and 61:

"By reference to the horizontal view, it will be seen that it is a direct and double acting steam piston pump, having a plain slide-valve, similar to the ordinary D-valve of an engine. This valve is moved

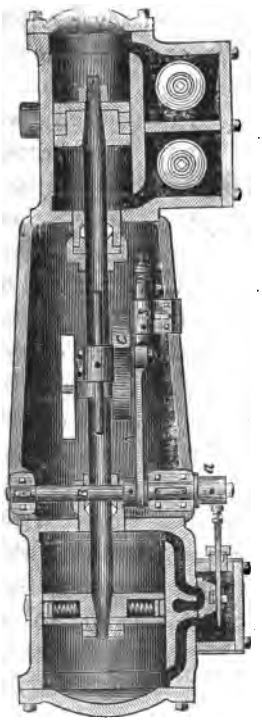


Fig. 60.—Sectional Plan, Regular Pattern Cam Pump.

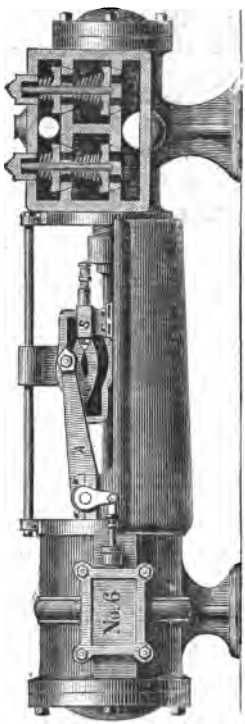


Fig. 61.—Sectional Elevation, Regular Pattern Cam Pump.

by two levers *A a*, on a shaft, *B*, being placed at right angles, forming a bell lever. Motion is imparted to these levers by a cam, *C*, bolted to the piston rod and working with it, a pin on the lever, *A*, working in a groove of the cam, *C*; also a fixed sup-

port or pocket, *S*, which holds a sliding V-shaped plunger, *P*, and spiral steel spring. The operation of the valve movement is as follows: "The cam, *C*, near the termination of the stroke of the pump piston, brings the V-shaped, or pointed lever, *A*, in contact with the V-shaped plunger, *P*, forcing it back in the pocket, *S*, and compressing the spiral spring contained in the pocket. The movement of the piston continues until the points have passed, when the forcible reaction of the spiral spring and the pressure of the incline faces of the V-shaped points serve to move the lever, *A*, and through the small lever, *a*, to throw the steam valve sufficiently to partially open the steam port for the return stroke. The same operation is performed on the return stroke. At its termination, only the lever, *A*, is thrown in the opposite direction. The arrangement of the water valves is extremely simple; the pump being double acting, there are two suctions and two discharge valves, all contained in one water box on the side of the water cylinder. By reference to the sectional view of the water box, a clear idea is obtained of the arrangement of the valves, valve seats, stems, springs and plugs, and the manner of putting them in. This pump possesses what all pumps should, and that is, large steam and water passages. By an inspection of the details of its moving mechanism, it will be seen that it can never make a short stroke. Each stroke must be complete before the steam valves will open to cause it to make a stroke in the opposite direction."

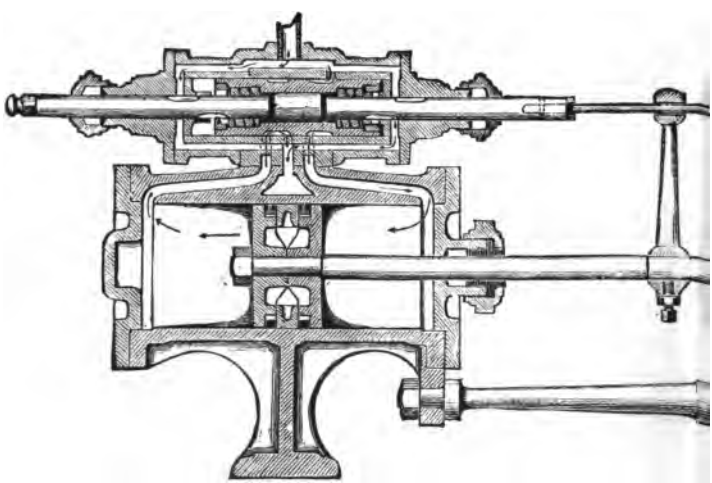
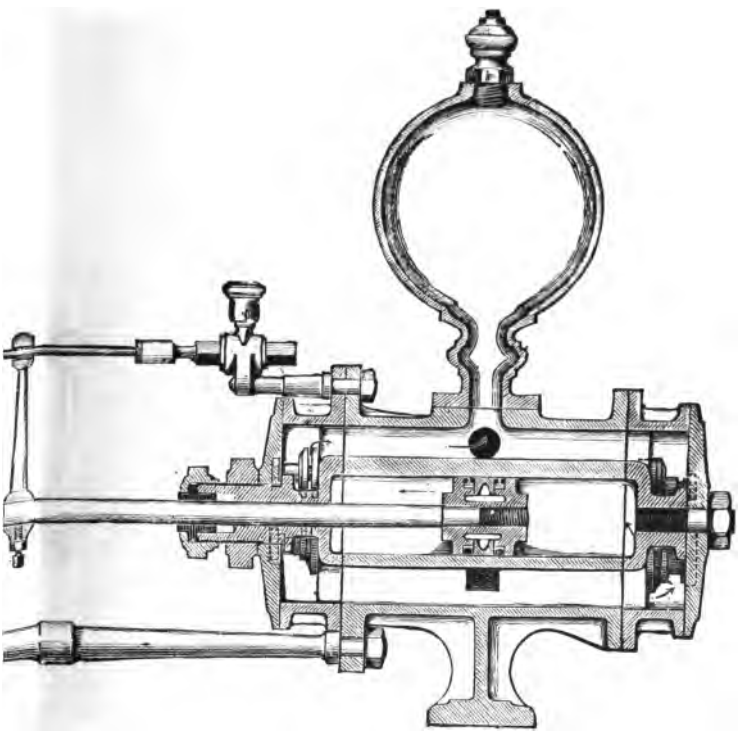


Fig. 62.—Sectional View of the Na



THE NATIONAL STEAM PUMP. Page 221.

National Steam Pump. (Fig. 62.)

Made by Wm. E. Kelly & Bro., New Brunswick, N. J.

Simplicity.

The steam valve of this pump is very simple in construction, and can be easily understood by any ordinary mechanic, and therefore possesses the great advantage that it can be renewed and properly adjusted by the engineer in charge, without sending the pump back to the manufactory. The main valve is the ordinary cylindrical slide-valve familiar to all engineers.

Certainty of Action.

This pump has no "dead-centres," where it will stop. It will start from any part of the stroke without the use of any starting bar or hand work to get it over the centre; and one of the especial points of excellence which it possesses over other pumps is, that it will work its steam valve with water, and will start even if the steam pipe is filled with the water of condensation, as is very often the case in factories where the pump is not in continual use. The importance of this every engineer will fully appreciate.

Durability.

All the material used in the construction of these pumps is of the very best. The piston rods, valves, valve seats, and the linings in the water cylinder, are of the best composition metal.

High Speed.

In most pumps, where the main valve is operated by steam admitted by a small auxiliary valve, when moving at a high speed, the steam will not work the main valve quick enough, and consequently the piston strikes the head of the cylinder. This objection is entirely overcome in this pump. When running slowly, the steam operates the main valve, but if, in running rapidly, the steam should not operate the valve quickly enough, then the momentum of the main piston and rod, which is connected direct with the valve rod, by means of a tappet, will reserve the valve and thus change the direction of the piston before it can strike the cylinder head, so that at any speed there will invariably be a full port of steam for the return stroke before the piston reaches the end of the stroke.

Economy.

The water passages are very large and ample, and in consequence of the valves being in the cylinder heads all crooked and complicated water passages are done away with, thus reducing the loss of power caused by the friction of the water in turning short corners in crooked passages, and making the pump work with greater ease and economy.

Facility of Repairs.

The water cylinder of this pump is a novel feature. The valves and valve seats are placed

in the cylinder heads, and are easily removed or replaced without disturbing the air chamber, suction or discharge pipe.

All parts are made interchangeable, so that in case of wear or accidental breakage, duplicate parts can be supplied without the trouble or annoyance of taking out the pump and sending it to the manufactory.

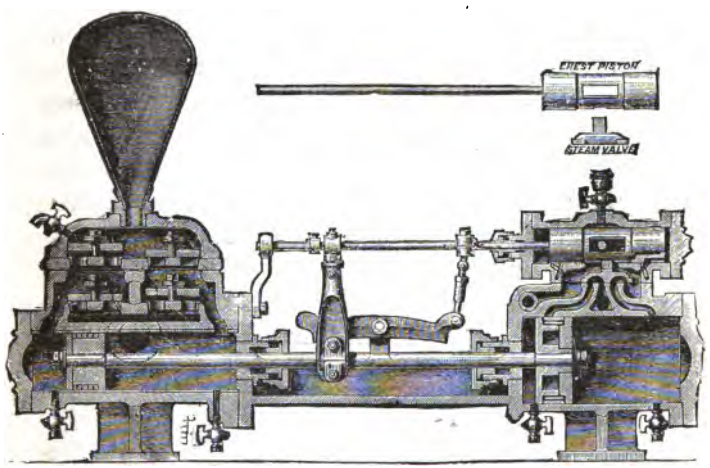


Fig. 63.—Knowles Patent Steam Pump—Sectional View.

The Knowles Patent Steam Pump. (Fig. 63.)

It is conceded that the direct acting, positive motion steam pump originated with Mr. L. J. Knowles. Since the first he has made more steam pumps than any other manufacturer, adapting them to every conceivable requirement, improving them in every part where costly experiment and wide expe-

rience has shown that they could be improved; and it is now claimed, that these pumps, in their manifold varieties, for efficiency, durability, simplicity, and certainty of action, are equal to any in the world.

By "direct acting" is meant a pumping engine having a steam piston and one or more water pistons or plungers attached to one piston rod, all having equal motion on central or parallel lines.

By "positive motion" is understood a valve motion with such arrangements of parts that the valve can never be in such a position that the pump will not at once start on admission of pressure, either of air, water, or steam.

These pumps are symmetrical in outline, having great strength without excessive weight or clumsiness. Material and workmanship is of the very best throughout, as good in every respect as in the best modern locomotives. All parts are made interchangeable. Cylinders are made from iron specially adapted to the work required. Water cylinders, when used for pumping liquids requiring it, are made of, or lined with, the best quality of "gun metal" (government standard).

Piston heads, both steam and water, have carefully fitted rings or packings of such design and material as years of experience has proved most suitable for the work required.

The piston rods, stuffing boxes, and glands, on all small and medium sizes are of best "gun metal." The larger sizes have rods of steel or cold rolled iron, with composition coverings.

These pumps are made long connected, thereby giving easy access to stuffing boxes, and preventing the piston rod running from live steam into cold water, thereby obviating the consequent leaking and tearing away of stuffing boxes, loosening pistons, breaking piston rods, etc., inevitable to all "short connected" pumps.

In the steam chest there are only "two pieces," the valve (which is a flat slide valve), and the valve driving piston, and each being made all in one piece make only two moving pieces in the steam chest, to produce the entire motion.

The steam valve of the pump, being an ordinary flat slide valve, does not have a rotary motion but simply a horizontal motion, the same as any slide valve. This style of flat valve embodies the most favorable possible conditions for tightness, even after the wear consequent upon a long use.

The slight rotary motion imparted to the valve-driving piston, by the rocker arm, simply puts it in a position to be driven horizontally by the steam, in which motion it carries the slide valve with it, both being directly connected together. This pump has always been made with a plain slide valve, and having only two moving pieces in the steam chest, is consequently the most simple, durable, and positive pump in existence.

It has no spring, screws, yokes, nuts, followers, rings, plunger cushion springs, movable seats, poppet valves, or studs, inside of the steam chest. The

driving piston is entirely independent of exhaust steam for cushioning, thereby working with the same certainty and exactness when exhausting into vacuum (working condensing), as when exhausting into atmosphere. It will also work equally well in a vertical as in a horizontal position; these are both valuable and distinctive features of this pump.

It runs with less clearance in the steam cylinder than some other steam pumps, thereby economizing steam. It will run at any speed, very slow or very fast. The joints are ground to fit, and require no packing. It will always start at any part of the stroke, and has no dead points whatever.

Patented improvements recently applied, insure entire freedom from "jar" or "pounding" under every condition of pressure, and "still running" at a higher speed than has been attainable with any other pumping engine. The water ends of these pumps have unusually large openings—ample valve area, and are of easy access. The valve-seats are composition, and the valves can be either rubber, clack, hinge, poppet, disk, cup, cage, or ball valves; also, water pistons of every known variety, to suit the required work.

All the parts are made actually interchangeable and to fit. Every pump can be taken apart without disconnecting the pipes. The patent hot water piston is self-adjusting and always tight and easy running. The water valves can be taken out and replaced almost

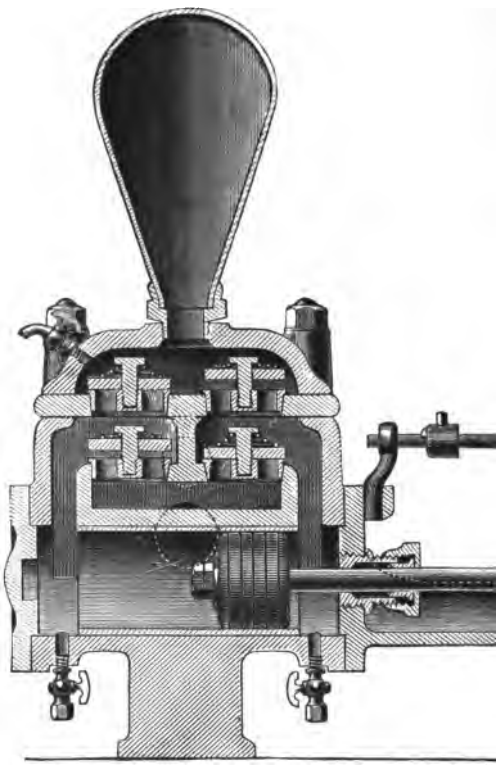
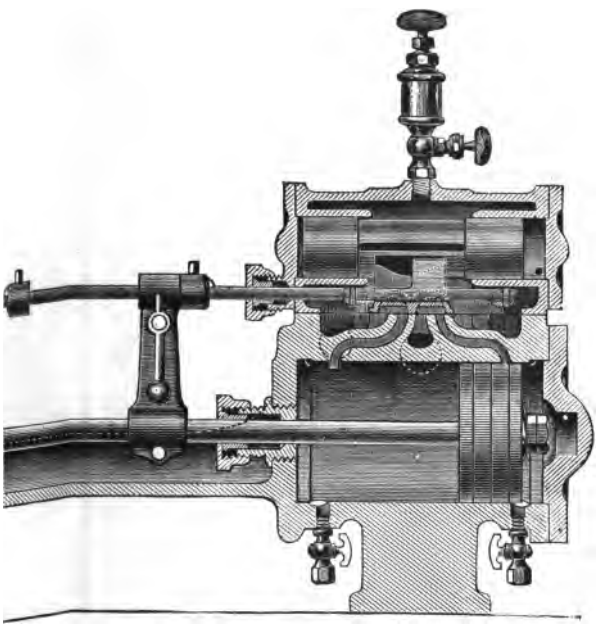


Fig. 64.—DEANE'S PATENT STEA



r STEAM PUMP. (*Sectional View.*) Page 227.

instantly. It has larger ports and less friction than any other pump.

The best hand power attachment in use, secured by letters patent; it does not necessitate the cutting away of any part of the pump to attach it. It is invaluable for filling boilers when steam is down, etc., and can be removed by simply lifting it from its rests. It is conceded by the best engineering talent, that the workmanship is equal to any machine of its kind produced in this or any other country. They are made by the Knowles Steam Pump Works, Warren, Mass.

Deane's Patent Steam Pump.

As no rotary motion is developed in direct-acting steam pumps, by means of which an eccentric can be made to operate the valve, it is necessary to reverse the piston by an impulse derived from itself at the end of each stroke. This cannot be effected in an ordinary single valve engine, as the valve would be moved only to the centre of its motion, and then the whole machine would stop. To overcome this difficulty without having recourse to the momentum derived from a fly-wheel, a small steam piston is provided to move the main valve of the engine. This small or supplemental piston as it is called, being operated in its turn by a small valve which is moved by power derived from the main piston when near the end of its stroke.

In the Deane patent steam pumps, the tappit arm (Fig. 64), which is carried by the piston rod, comes

in contact with the tappit, when near the end of its motion, and, by means of the valve rod, moves the small slide valve which operates the supplemental piston. The supplemental piston, carrying with it the main valve, is thus driven over by steam, and the engine reversed. If, however, the supplemental piston fails accidentally to be moved, or to be moved with sufficient promptness by steam, the lug on the valve rod engages with it and compels its motion by power derived from the main engine.

The peculiar excellence of the Deane steam pump consists,

First, in the unequalled simplicity of its mechanism. Its valve gear consists of fewer pieces than are found in any other pump. All the parts move on parallel lines, and central to the same vertical plane, so that all levers, connecting rods, rocker arms, springs, adjustable screws and other mechanical complications are avoided. Both the main valve and the supplemental valve are flat slide valves, readily understood and easily reseated in case of wear. The supplemental piston is in one piece, and it is a piston, not a valve.

Second, in the certainty of its action. The supplemental piston, which has a compensating steam jacket, is driven by the direct pressure of steam on alternate ends, complemented when necessary by the whole power of the main engine, so that it runs equally well vertically or horizontally, exhausting into open air or into a condenser. The mechanical connection

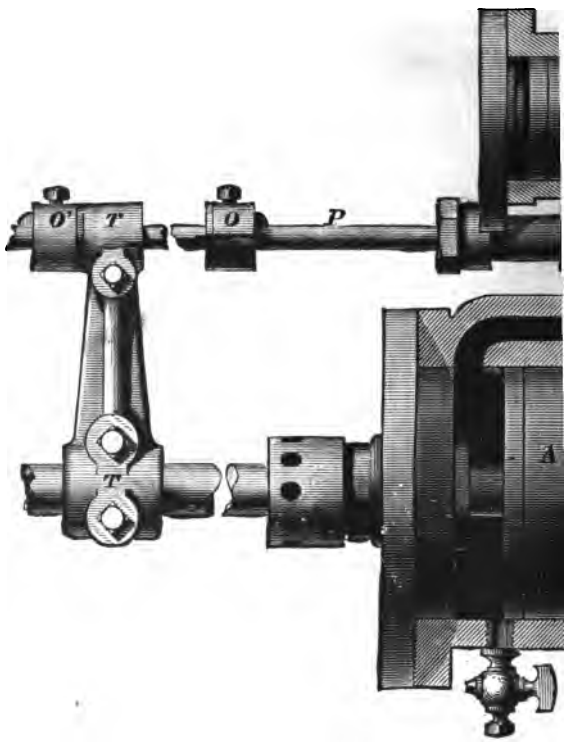
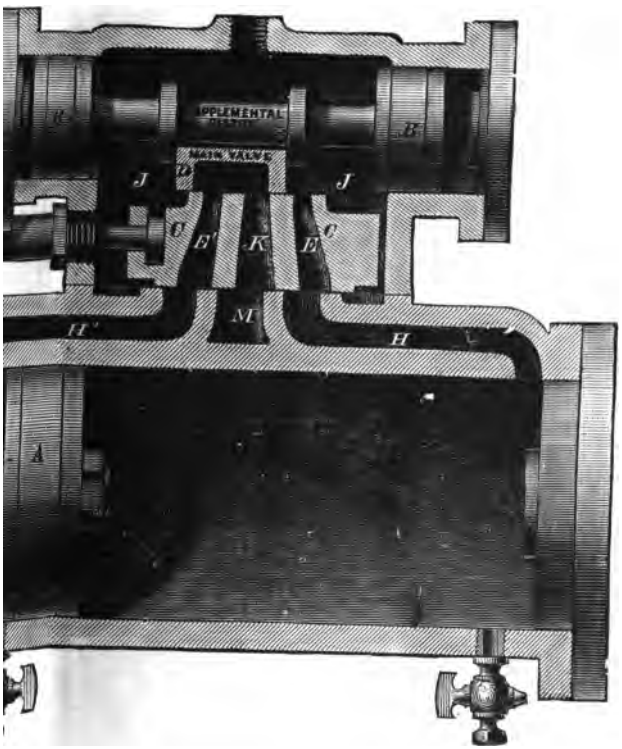


Fig. 65.—The Blake S



KE STEAM PUMP. Page 229.

renders it absolutely certain that the valve shall always lead the piston, so that there is no possibility of any pounding on the cylinder heads, and the clearance in the cylinder is reduced to the minimum. The machine, simple, yet lacking nothing essential to a perfect pump, is always ready and in position to start at any point in its stroke, on the admission of water, air or steam, and to run at any speed desired, either the fastest or the slowest.

The Blake Steam Pump.

Fig 65 shows the steam valves, valve gear, etc.

The Blake patent steam pump is absolutely positive in its action—that is to say, the operation at the slowest speed, under any pressure, is perfectly continuous, and the pump is never liable to stop as the main valve passes its center. An ingenious and simple arrangement is used in the Blake pump to overcome the "dead center," as will be seen from the following description of the

Operation:

The main or pump driving piston *A* could not be made to work slowly were the main valve to derive its movement solely from this piston; for when the valve had reached the center of its stroke, in which position the ports leading to the main cylinder would be closed, no steam could enter the cylinder to act on the main piston, so that the latter would come to rest, since its momentum would be insufficient to keep it in motion, and the main valve would remain

in its central position. To shift this valve from its central position and admit steam in front of the main piston (whereby the motion of the piston is reversed and its action continued), some agent independent of the main piston must be used. In the Blake pump, this independent agent is the supplemental or valve driving piston *B*.

The main valve, whose movement alternately opens the ports for the admission of steam to and the escape of steam from the main cylinder, is divided into two parts, one of which, *C*, slides upon a seat on the main cylinder, and at the same time affords a seat for the other part, *D*, which slides upon the upper face of *C*. As shown in the engravings, *D* is at the left-hand end of its stroke, and *C* at the opposite or right-hand end of its stroke. Steam from the steam-chest, *J*, is therefore entering the right-hand end of the main cylinder through the ports *E* and *H*, and the exhaust is escaping through the ports H^1, E^1, *K* and *M*, which causes the main piston *A* to move from right to left. When this piston has nearly reached the left-hand end of its cylinder, the tappet-arm, *T*, attached to the piston-rod, comes in contact with and moves the valve rod collar O^1 and valve rod *P*, and thus causes *C*, together with the supplemental valves *R* and *S* S^1, which form with *C* one casting, to be moved from right to left. This movement causes steam to be admitted to the left-hand end of the supplemental cylinder, whereby its piston *B* will be forced towards the right, carrying *D* to the opposite

or right-hand end of its stroke; for the movement of S closes N (the steam port leading to the right-hand end), and the movement of S^1 opens N^1 (the steam port leading to the opposite or left-hand end), at the same time the movement of V opens the right-hand end of this cylinder to the exhaust, through the exhaust ports X and Z. The parts C and D now have positions opposite to those shown in the engravings, and steam is therefore entering the main cylinder through the ports E^1 and H^1, and escaping through the ports H, E, K and M, which causes the main piston A to move in the opposite direction, or from left to right, and operations similar to those already described will follow, when the piston approaches the right-hand end of its cylinder. By this simple arrangement the pump is rendered positive in its action—that is, it will instantly start and continue working the moment steam is admitted to the steam-chest.

The main piston A cannot strike the heads of its cylinder, for the main valve always has a lead, or, in other words, steam is admitted in front of the piston just before it reaches either end of its cylinder, even should the supplemental piston, B, be tardy in its action and remain with D at that end towards which the piston A is moving, for C would be moved far enough to open the steam port leading to the main cylinder, since the possible travel of C is greater than that of D.

The result of this ingenious combination of valves

is a perfectly continuous action without any dead point. This result is attained without any complex internal arrangement, and without the presence of any parts which are liable to get out of order. The valve gear is in fact most simple in its character. Of the excellent working of the Blake pump at extreme ranges of speed, we are enabled to speak from personal observation.

The pump tested was first worked very rapidly and then set to a speed which for slowness and perfect continuity has never been equaled in our experience. With the delivery throttled to represent a head pressure of water of 230 feet, and with an average steam pressure of 40 pounds, this pump ran, or rather crawled, at the rate of five strokes per hour, delivering water throughout.

It is needless to observe that such a low speed as this would not be required in practice, but it illustrates the reliability of the Blake Pump either in quick or slow working. The pump was then put to work under rapidly varying loads, and throughout acquitted itself most creditably, affording ample foundation for the opinion we have already expressed —that it will not fail to establish for itself as high a reputation in England as it has in America.

CHAPTER VII.

INJECTOR.

THE injector was invented by M. Giffard, of France. The invention of the injector for supplying feed-water to the boiler of an engine is principally remarkable as presenting an illustration of the direct conversion of heat into work. Before describing the apparatus it will be necessary to explain the meaning of the term 'induced current.'

Looking back historically it appears that in 1719 Hawksbee, the inventor of a double cylinder air-pump, showed that when a current of air was sent through a small box—entering by an opening at one side near the top and escaping by a corresponding opening at the opposite side—the effect was to rarefy the air within the box rather than to compress it. It is an old experiment to suck up and drive a jet of spray out of a bottle by blowing through a horizontal tube with a contracted nozzle whose end is placed just over a vertical tube dipping into water contained in the bottle. The current of air passing over the open mouth of the vertical tube carries away some of the air from inside the tube, whereby the water rises to the top and is dispersed in a jet of spray.

According to theoretical definitions the particles

of gases repel one another and have no coherent action among themselves. In practice this is not the case; and if a definite current of air be set up in a mass of air at rest, as when a jet escapes from the mouth of a tube, the air in motion will drag a number of the quiescent particles with it and will extend considerably the dimensions of the original current. It will, in technical language, induce a current also in the surrounding air.

The application of an induced current, with which we are now concerned, is exhibited in Fig. 66. The globular vessel represents a boiler in which high pressure steam is generated, and from which it escapes at an orifice, E. The steam is discharged just inside a conical casing or nozzle, the object of which is to provide a means for setting up an induced current of air which will speedily exhaust the tube. The water forced up by atmospheric pressure to supply the loss of air, will, therefore, issue from E, and we shall have made the first step towards the construction of an injector, viz., the discharge through E of a mixed jet of steam and water. Fig. 67 shows a Giffard injector, as made by Wm. Sellers & Co., Philadelphia, Pa. There is a pipe marked "steam," which terminates in a vertical conical nozzle, having within it a solid rod or needle capable of contracting in any degree the amount of the issuing jet. On the opposite side of the apparatus is a pipe marked "water," which corresponds to A B in the elementary diagram, and by turning the wheel marked "water

regulator" the tinted sliding tube is brought up or down, so as to regulate the supply of water which is sucked up by the inducing action of the steam.

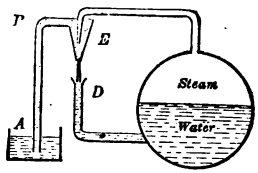


Fig. 66.

There is here, therefore, precisely the apparatus already described, together with the mechanical means for regulating the supply of steam and the supply of water.

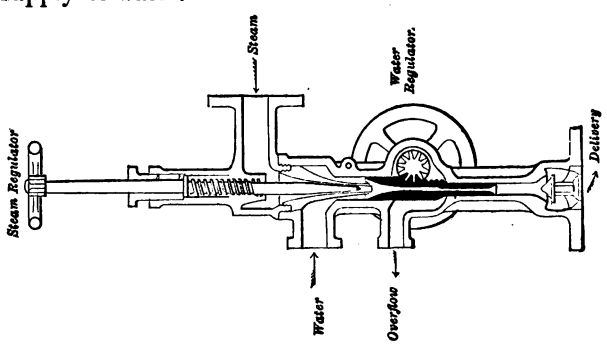


Fig. 67.

At one end of the injector is a valve opening outwards, leading to the flanged and marked "delivery," which is in direct communication with the boiler. This valve is shown open in the figure, but it is closed

by the pressure in the boiler when the injector is not at work.

Looking again at Fig. 66, which is intended to show the action in its most simple form, we may point out that M. Giffard discovered that a jet of mixed steam and water, issuing from E under the circumstances above stated, is competent to overpower and drive back a simple jet of water issuing from the opening D, and that a supply of feed-water may be forced into a boiler by the steam generated therein without the use of any pumping apparatus whatever.

Since action and reaction are equal and opposite, it is abundantly clear that a simple jet of high pressure steam issuing from E could never drive back a jet of water issuing from D under the same pressure. It was a great step in science to conceive the idea that the absorption of heat which took place at E could furnish a source of energy directly available for doing work. There has been no parallel to this discovery in any analogous direction, and it is difficult to account for the action.

On the steam side there is the kinetic motion of the molecules of steam, and on the water side there is the motion of translation of a quantity of water, and the problem is to show a possible method of passing from the one to the other. Now, the steam issuing at E has a velocity many times greater than that of the water forced out at D. The instant that steam is liberated and escapes, the kinetic motion of

its particles appears under a new form, viz., as a motion of translation, and the velocity of an issuing jet of steam is many times greater than that of a jet of water forced out by the same pressure. If, therefore, the jet of steam could be condensed by an indefinite source of cold after it had fairly got clear of the orifice, it would be converted into a fine liquid line, and the velocity with which its molecules were rushing out would not be changed. The motion of heat would be diminished, but the onward motion would remain unimpaired. This liquid line would be moving at such a high velocity that it would pierce any jet of water coming towards it from the boiler, very much as if it were a steel wire forcing its way through the mass. We know of no source of cold competent to produce this result, but what really happens is the same in character though less in degree. The steam, liquefied at E, retains to some extent the higher velocity which it possessed as steam, and on the whole the aggregate energy of the water globules flowing onward at E is greater than that of the water jet coming towards them from D. The latter jet is overpowered and driven back, and a quantity of water from the cistern at A is continually forced into the boiler.

As to the velocities with which we have to deal, it appears that if the steam had an actual pressure of six atmospheres the water would issue at a velocity of about 101 feet per second, and the steam at a velocity of about 1,800 feet per second.

Referring again to Fig. 67 it will be seen that a pipe marked "overflow" leads out from the centre of the instrument; this pipe communicates with a small chamber in the central channel just below the level of the pinion, and is intended to allow the escape of any surplus water. When the supply of steam is properly adjusted to the amount of water sucked into the instrument no overflow takes place, whereas an access of water or steam will at once give rise to a discharge at the overflow. In the one case the energy imparted to the water is insufficient and part recoils, while in the other case too great a condensation of steam will occur and energy will be dissipated. It is, however, easy to adjust the steam and water regulators so as to avoid any waste.

The rise in temperature of the feed-water shows the amount of energy available for doing work, and it is found that the quantity of water delivered into the boiler increases as the feed-water itself is supplied in a colder state. Thus, in one case, the temperature of the feed-water before entering the injector was 60°, 90°, 120°, and the number of gallons of water delivered per hour was 972, 786, 486 respectively. It is a confirmation of the explanation that steam at a given pressure will force water into a boiler against a still higher pressure. Thus, steam at 27 lbs. pressure forced water into a boiler where the steam was at 52 lbs. pressure, the temperature of the feed-water being raised from 92° to 170° during the operation.

The "1876" Injector,

By William Sellers & Co., Philadelphia, Pa. The introduction of the Giffard injector in this country was made by William Sellers & Co., of Philadelphia, in 1860, and they were, during the continuance of the original patent, the sole licensees and manufacturers under that patent in the United States, and have made, from time to time, improvements in the instrument. In 1865 they introduced the novel and important principle of self-adjustment. Previous to this, injectors had either fixed nozzles or were arranged with independently adjustable nozzles, separately operated to adapt the steam and water-supply to each other, and to the changes in the boiler pressure, etc. In these injectors any want of proper adjustment was indicated either by a waste of water or in-draught of air at the overflow, and if, after a most careful adjustment of the parts to produce the best results, the steam pressure in the boiler changes, the instrument would work badly until readjusted for the new conditions. The self-adjusting instruments have no waste at the overflow. After starting, the steam-supply alone is adjusted by hand, and the water-supply is automatically regulated, so that the steam is always combined with the exact quantity of water necessary to produce the best results, no matter how much the steam pressure in the boiler may vary. This instrument in its improved form went through various changes for the better up to the year 1876, when a new style, the "Injector of

1876," was exhibited at the Centennial, after careful tests on leading railroads.

The advantages of using an injector to feed steam boilers are, that it may be operated to deliver the water in a continuous stream, and furnishes heated water at all times.. To obtain the full advantage of the injector the manipulations of the instrument required to start and regulate the feed should be simpler than those necessary in the use of the pump. The "Injector of 1876," a sectional view of which is shown in Fig. 68, was designed to accomplish this object, and is put in operation and regulated entirely by moving a single handle. The connection to the boiler, and those for the admission of steam and water, are clearly designated in the figure, the latter being provided with a suction chamber to steady the flow. A fixed receiving-tube, through which the principal jet of steam passes, is regulated by the position of the interior conical spindle. The annular jet of steam combines with water in the combining-chamber, and the concentrated jet is forced through a delivery-tube, and the check-valve shown, to the boiler. The combining-tube forms part of the piston, which fits freely into the case, and the smaller end of combining-tube slides freely also in the end of delivery-tube. The pressure of the water is on one side of the piston, and the other side is in communication with the jet issuing from combining-tube through an opening inside of delivery-tube. If the water-supply be

too great, a portion escapes through an opening

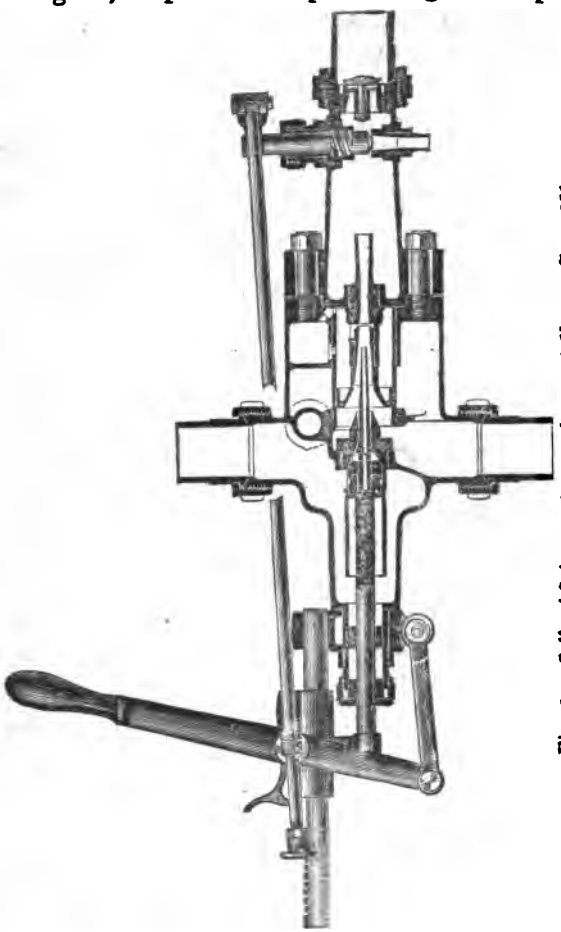


Fig. 68.—Sellers' Injector of 1876 (*Sectional View*). Page 239.

and accumulating in the surrounding chamber, forces

the piston and combining-tube towards the receiving tube, and contracts the annular space between the two latter, so that the water-supply is reduced. If the water-supply be insufficient, a partial vacuum will be produced in the chamber, and the piston moved to admit more water. In this manner the supply of water is automatically adjusted to suit all the requirements.

The description thus far is common to all the Sellers' self-regulating injectors. In the "Injector of 1876," the central spindle shown in the receiving and combining-tubes is secured to an operating-spindle, and has a small bore throughout its length, which receives steam through small openings, when the valve on operating-spindle is raised from its seat in the top of the larger valve, which admits steam to the receiving-tube around the central conical spindle. The operating-spindle is moved through the arm and slide shown, by the operating-lever; and the latter, also, by means of the rod, with stops upon same, operates the screw overflow-valve on stem. In the position shown, steam is shut off, and the overflow-valve is open. Upon moving the lever the valve is first opened, and the steam is first admitted to the small bore of central spindle, and issues in a jet, which induces a current in the water-supply pipe, whereby the air is withdrawn—water lifted and expelled at the overflow. [The lifting effect desired is quite dissimilar from the action of the annular jet in operation as a boiler feeder, being

more nearly allied to the action of the exhaust in producing a draught in the smoke-pipe of a locomotive, and requires a high velocity and free expansion at the moment of escape.] When the water is lifted by moving the handle still more, a collar on the central spindle comes in contact with and opens the large valve, thereby admitting steam to the annular jet to produce regular operation, as previously described, and the handle, upon being moved back to its extreme strikes the stop on the rod, and thereby shuts the overflow. At the same time a pawl drops into a rack on the arm, and holds the lever in position when the latter is pushed in to regulate the flow. This pawl is lifted and caught fast, when the lever is pushed entirely in to stop the injector, and not relieved again till the lever is at the other extreme, as above explained. The instrument can be located in any convenient position on the locomotive above the water-level, as it is considered advantageous to have the injector lift its supply of water.

The Hancock Inspirator.

The Hancock Inspirator, Fig. 69, differs in some important respects from the instruments commonly classed under the head of injectors. It consists essentially of a lifting-jet and lifting-nozzle, combined with a forcing-jet and force nozzle or injector, steam being admitted to both of these nozzles whenever the inspirator is in operation, to deliver the supply-water to the force-nozzle, and to force it through

this nozzle into the boiler. Although both the lifting and force-nozzles are fixed, their proportion one to

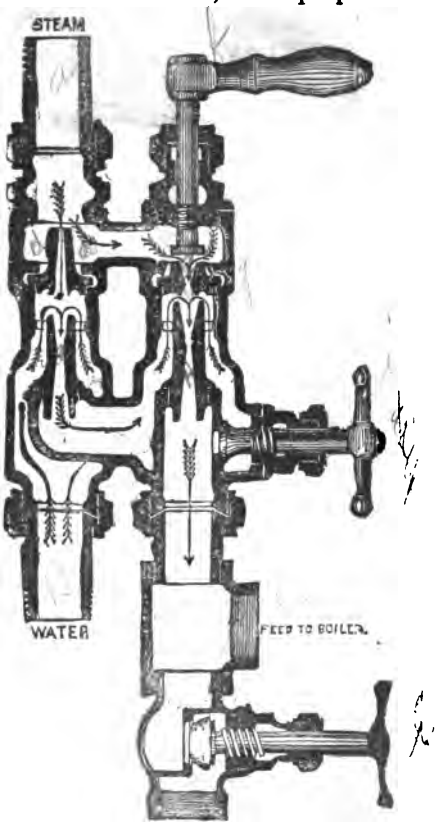


Fig. 69.

the other is such that the inspirator requires no ad

justment for changes in steam-pressure or water-supply, the waste-valve being kept closed while the instrument is in operation, except at the time of starting. The sectional view of the stationary inspirator, Fig. 69, will serve to explain the action of the instrument. In this figure, A is the steam-supply pipe, connected to the steam-space of the boiler; B is the water-supply pipe; and C is the feed-pipe, to which is connected an overflow or waste-pipe with waste-valve, these latter connections not being shown in the figure. D is the lifting-jet, E the lifting-nozzle, G the forcing-jet, and H the force-nozzle. This latter nozzle is somewhat analogous to the combining-tube of an ordinary injector. F and I are stop-valves, the first controlling the admission of steam to the forcing-jet, and the latter determining the course of the water delivered by the lifting-jet. The action of the inspirator can perhaps be most simply explained in connection with a description of the manipulation required to start the instrument. In the figure, the inspirator is represented in operation; but when it is not working, a steam-valve in the pipe A, not shown, is closed, as is also the valve F, while the valve I and the waste-valve are open. Opening the valve in the steam-supply pipe A, steam is admitted to the lifting-jet D, drawing water through the supply-pipe B, and discharging it through the lifting-nozzle E, valve I, waste-valve, and overflow-pipe. As soon as water issues from the overflow-pipe, the valve I is to be closed, when the

supply-water will pass through the force-nozzle H, and will escape at the overflow. The valve F is then to be opened, by moving the lever K one-quarter turn, and the waste-valve is to be closed, when the water lifted and delivered to the force-nozzle H will be forced into the boiler by the steam issuing from the forcing-jet G. If the water supply is to be varied, this can be effected by partially closing a valve in the supply pipe B without throttling the admission of steam; or both the steam and water may be throttled if desired. In practice, however, the delivery is varied by throttling the water-supply. Whatever changes of adjustment are made, whether of steam or water-supply valves, within the capacity of the inspirator, the instrument will continue in operation with the waste-valve closed. In this respect the inspirator differs materially from fixed-nozzle injectors, which cannot be operated with the waste closed, under the conditions recited above.

The Rue Little Giant Injector,

Made by the Rue Manufacturing Company, Philadelphia, Pa. The principle of its operation is as follows:

As the steam is coming from the boiler, it enters the steam plug. Here it is joined by the water, which enters and fills the combining tube; here the steam gives the water a velocity, is condensed, and a water jet is formed and driven across the overflow space, and enters the discharge plug; thence past a

check valve, which is generally placed a few inches from the injector, into the boiler.

During the passage of the water from the combining tube to the discharge plug, as it passes over the overflow space, if too much water has been supplied to the steam, some will escape, and flow out of the overflow nozzle; for the reason that the pressure of steam is not great enough to give that amount of water the necessary velocity, in order that it may have sufficient power to overcome the resistance of the boiler pressure; hence, the water and condensed steam or mixture, as it is generally termed, must pass out at the overflow.

This will go on until we reduce the water-supply. This is done by moving the lever to the right, which will move the combining tube nearer to the steam plug, thereby reducing the supply of water until the steam can give it the required velocity, and, when this has been obtained, there will be no discharge of water at the overflow.

The injector being at work perfectly, we will suppose that the pressure of steam has been gradually increasing, which likewise increases the velocity of the water in the combining tube, until it is driven through faster than it can be supplied, and air will be drawn in at the overflow; but this is prevented by the small check-valve. Whenever this occurs, we are generally warned by a peculiar sound coming from the injector.

This will go on until the amount of water is not

sufficient to condense the steam and be at a less temperature than 212° Fahr., which will cause the formation of steam, which is very light, although, with its high velocity, it has not sufficient power to overcome the boiler pressure, and must, consequently, pass out at the overflow in the form of a very wet steam, so to speak.

From the above it will be seen that although the velocity of the mixture of a temperature above 212° Fahr., or when the formation of steam takes place, is much higher than that of a mixture in which this formation does not take place, the power of the former is much less than that of the latter, "because the total actual energy is proportional to its *weight* multiplied by the square of its *velocity*."

To illustrate this in a very simple way, let the reader procure two wooden balls of the same size, one of a hard and heavy, and the other of a soft and light wood.

Either of these balls will float on the surface of a body of water, and it will require some force to sink it; but take them up, and throw the heavy one, for example, with some velocity upon the water, and it will sink to a considerable depth before the resistance of the water will overcome its momentum or actual energy. Now take the light one and throw it with the same velocity, and it is doubtful if it will sink more than a few inches. This goes to show that the weight has a great deal to do with the power of the mixture, in the working of the injector.

Another important point that should not be overlooked is that of the temperature of the feed-water.

So long as it is desirable to have the operation of the injector as perfect as possible, the temperature of the feed-water should not exceed certain limits, as it is necessary that the steam should be completely condensed.

In order that this may be as perfect as possible, and the operation of the injector the same, the feed-water must be cold enough to absorb the proper number of heat units that the steam contains, and be at a less temperature than 212° Fahr.

It may be well to state here that the operation of the injectors of the ordinary form ceases; that is to say, they will not do the work, after the mixture reaches or exceeds 200° Fahr.

The greatest temperature of feed-water will, generally speaking, depend upon the pressure of steam. When the pressure of steam is high, the temperature of the feed-water must be lower than when the pressure is low. The greatest temperature of feed-water, in either case, can best be determined by experiment.

By carefully considering the foregoing, it is obvious that the amount of water that the injector throws must increase in proportion to the amount of steam used, when the temperature of the feed-water is raised.

It is obvious that it requires a greater amount of

water to condense the steam, and be at a lower temperature than say 195° Fahr., than it would if the temperature of the feed-water were lower.

From what we have already stated, it will be seen that when the amount of water is large in proportion to the amount of steam, the velocity of the mixture also diminishes. This also applies to the above, when the temperature of the feed-water is raised.

With a certain pressure of steam and temperature

Fig. 70.—The Rue Little Giant Injector.

of feed-water, the power of the mixture may be just sufficient to overcome the boiler pressure; whereas, if the temperature of the feed-water is still increased, it will require a proportional amount of water to condense the steam; this will result in a proportional reduction of velocity, probably sufficient to render the power of the mixture valueless.

When the injector, shown in Fig. 70, is set so as to lift the feed-water, it is started by placing the

lever in a vertical position, and opening a small jet-valve which allows the steam to pass through a small pipe attached, which is connected to the small pipe, through which the steam also passes; and in so doing, draws all the air out of the injector and water-supply pipe, thereby creating a vacuum, which results in the pressure of the atmosphere raising the water in the pipe, and through the combining tube, thence out, and immediately appears at the end of the nozzle.

As soon as the water appears at the overflow nozzle, the main steam valve is gradually opened until it catches the water, when it is opened wide, and the small jet-valve is closed.

Should no water appear at the overflow, it shows that the injector is working all right.

Now, should the pressure of steam increase until the temperature of the mixture is high enough to cause the formation of steam, and a discharge of the same at the overflow, we must increase the water-supply until this discharge ceases; after the discharge ceases it may be preferable to still increase the supply of water until there will be a discharge of water at the overflow; then gradually reduce the supply of water—for this reason, that in the former case you may have admitted just sufficient water to keep the temperature of the mixture below, say 195°, and you may not have given it all the water that the stream would safely carry into the boiler.

The Korting Universal Injector.

As will be observed by Fig. 71, the instrument is a combination of two steam jet apparatus; the first

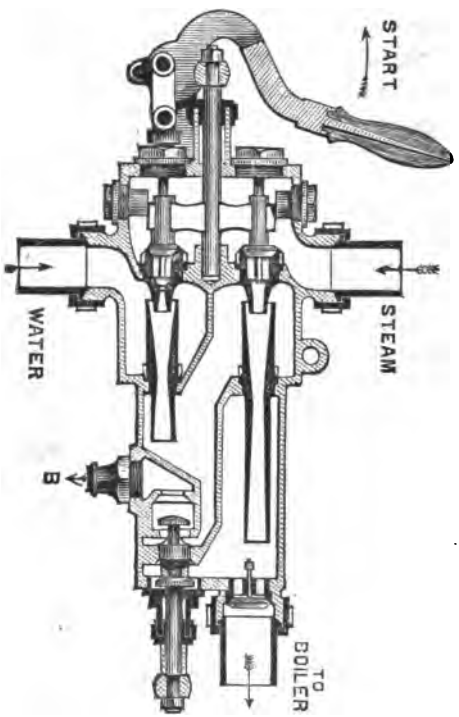


Fig. 71.—The Korting Universal Injector.

one proportioned for lifting and delivering the water under some pressure into the second one, where its velocity is sufficiently augmented to overcome the

counter pressure of the boiler. The explanation of the proper working of the injector, at the lowest as well as the highest steam pressures, without any adjustment of parts, is found in the fact, that the quantity of the water taken in by the first apparatus and delivered to the second one is directly in proportion to the pressure of the steam, so that the first one acts as a governor for the second one.

The explanation of the feeding of hot as well as cold water, is found in the construction and proportion of the first apparatus, which has a proportionately small steam nozzle to insure high suction, and as the water is delivered to the second one under pressure, its temperature can be corresponding to this pressure, and may be delivered into the boiler above the boiling point. At the same time the combined area of the two steam nozzles is smaller than that of any other injector of the same capacity, so that its duty must necessarily be higher.

This combination of the two apparatus, and its self-governing qualities without moving parts, makes the apparatus the least sensitive—a great desideratum on locomotives.

The limits of admissible temperature are: Feed-water 150 deg. Fahr. delivered into the boiler, with 150 lbs. steam at 250 Fahr. Injectors will lift water up to twenty feet, according to temperature.

Fixing the Injector.

The injector should, preferably, be fixed horizontal,

in which case it will drain itself when not in operation. The pipe should not be smaller than the corresponding size of couplings. The dirt stop should always be attached where the water is not perfectly clear. There should be a steam stop valve, and a main check valve on boiler. If water flows to the injector, it is necessary to have a stop valve in the water pipe.

Before connecting the injector, have the steam pipe well blown out with steam to clear it of scale and dirt. Do not omit to attend to this, as the nozzle openings are small, and if clogged with red lead or dirt, will interfere with, or stop, the action of the injector.

Manipulation.

If the injector has to draw the water, open with handle A, half-way first, till water is discharged through the starting cock B, then open full.

This stop need be of so short duration, that a continuous moderately slow movement will accomplish the required result; so that the instructions for manipulation would read: To start, open with handle A; to stop, shut with handle A. To regulate the quantity of water to a minimum, throttle the water in suction pipe, but keep steam turned on full all the time. Manufactured by Schutte & Goehring, steam jet engineers, Philadelphia.

The Keystone Injector,

Manufactured by E. Tracy, Philadelphia, Pennsylvania.

The following are some of the advantages claimed for this injector.

1st. Its simplicity, durability, and easy adjustment, requiring no skill to operate it.

2d. It is not affected by overheating, and will work under any pressure of steam from 5 lbs. to 160, and is not liable to break while working.

3d. It is void of all stuffing boxes. No extra fittings required for the two classes A and B.

4th. Its advantages over pumps. It is far cheaper. It is not necessary to run engine to fill boiler, as with engine or belt pumps. Thus saving fuel, repairs, oil, etc.

5th. The water by the use of this injector is heated to 200° Fahrenheit, hence no heater is necessary, and can be dispensed with, although it will feed through a heater same as pump.

6th. It will raise water as high as any other make, and can be regulated to supply more or less water as the case requires.

7th. Will lift and work water as hot as any other injector.

Non-Suction Injector "A."

This injector, Fig. 72, is used where the supply is received from a pressure, such as street mains, reservoirs, etc.

Method of Connecting.

It should be placed in a horizontal position, and lower than the tank, if water is taken from such, so it will receive a full supply. All pipes should be of the same internal diameter, to correspond with the injector coupling. Attach the steam pipe to highest part of boiler, and as short as possible, to obtain dry steam; but in no case make attachments

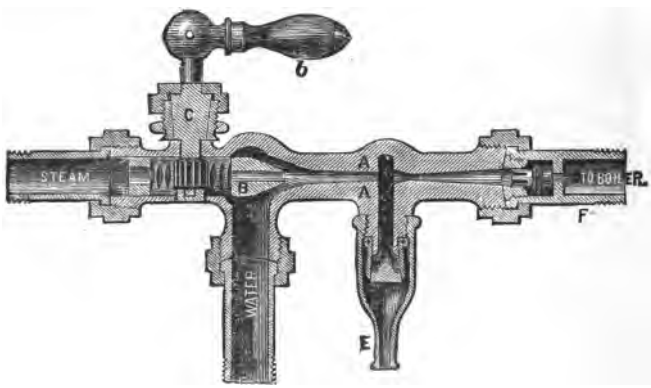


Fig. 72.—Non-Suction Injector "A."

to pipes supplying an engine, pump, etc., as it causes a variation in the steam pressure. Place an ordinary globe valve on steam pipe, a valve or water cock on water-pipe. (There is no necessity for an extra check valve on feed pipe near the injector, as there is one in the swivel marked to boiler.)

Use no washers or packing, as all joints are ground. Be particular, and remove all scale, cuttings and dirt from pipes, and see they are in perfect working order before connecting.

Method of Working Class "A."

First. Open the steam valve to leave out any condensed steam there may be in the pipe, and close it again. Then open the water cock, then the steam valve, and move the plug B slowly forward with the handle *b*, until the water ceases at the overflow. If, while the injector is working, water should escape from the overflow, move the plug forward to reduce the supply of water. If steam escapes, move the plug backward, to give it more water. When the lever *b* is set so the injector works perfectly dry, if you wish to stop feeding, close first the steam valve, then the water cock.

It is not necessary to disturb the lever *b*.

When wishing to feed again, the injector is put in operation by simply opening the water cock, then the steam valve. The lever is used to regulate the steam and water, and the necessity of using it will be shown at the overflow. If the lever *b* moves too loosely, tighten the nut upon spindle C; if too stiff, loosen it. This injector will force water through a heater.

The Suction Injector "B."

This class, Fig. 73, is applied where there is no pressure or head of water. For instance, when the feed-water is taken from a low cistern, river, pond, etc.

Method of Connecting.

Place the injector in a horizontal position, and

great care should be taken to have all joints air-tight; and it is best to place a piece of wire-cloth on the bottom of the water-supply pipe, to prevent floating particles from entering the injector. The jet D, used in this injector, serves to create the vacuum, and assists in carrying the water into the boiler; it being stationary, is always in proper position to produce a vacuum; and the steam necessary to carry the water into the boiler is simply obtained by moving the

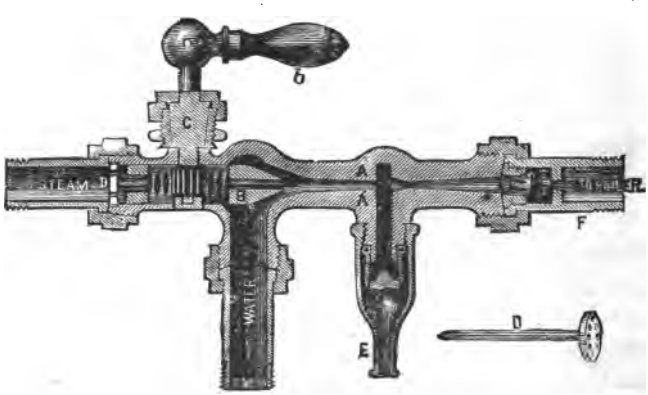


Fig. 73.—The Suction Injector "B."

plug *b*, without affecting the position or operation of the jet. All pipes should be of the same internal diameter; attach the steam pipe to the highest part of the boiler, as in class "A;" place an ordinary globe valve upon steam pipe; no valve or cock upon the water-supply pipe; see that all scale, cuttings or dirt are removed, and the pipes are in proper working order, and there is no dirt upon the plug B, or

disk of jet D, to prevent the proper closing of the perforations.

Method of working Lifting Injector "B."

Open the steam valve to remove the condensed steam; then close it again; move the plug B back tight against the disk of the jet D; then open the steam valve, and when water appears at the overflow, move the plug slowly forward until it ceases to flow. These injectors will lift according to their size.

Friedmann's Injectors.

Foremost amongst the distinguishing features of these injectors is the intermediate nozzle, by which the water supply is conducted in two annular streams to the condensing chamber of the injector, where the steam jet is subjected to the action of both at separate points. The result of this double action is the complete and effectual condensation of the steam jet, and the transfer without loss of all its inherent power and velocity to the water, now united in one column, and making its way with irresistible force and projection into the boiler.

The first stream also becomes a motor of the second, and carries it along without further expense of steam; this explains the marked difference in the quantity of steam needed to work these injectors in comparison with others.

Nearly all the other makes of injectors now before the public have but one waterway; in consequence

of which, the water-supply reaches the steam jet in a whole, unbroken mass, and coming in contact with this large body of water, the momentum of the steam jet is checked to a great extent and often only partially condensed, expands in the mass of water after passing the receiving nozzle; this breaks and confuses the column seeking to penetrate the boiler, and is the cause of much trouble and annoyance.

The Friedmann Injector, on the contrary, with the double waterway, before described, with fixed nozzles, and no movable parts, to get out of order, and having no *cam motion, no sliding or rolling levers, and no ground joints or packing* to require frequent adjustment, delivers the water with a steady, uninterrupted

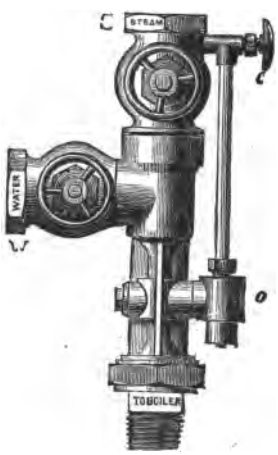


Fig. 74.—Friedmann's Lifting Injector.

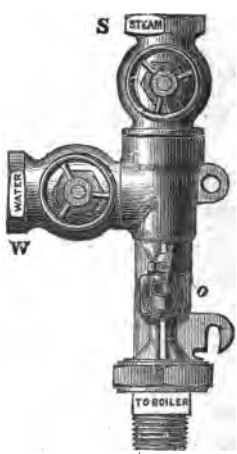


Fig. 75.—Friedmann's Non-Lifting Injector.

stream that no amount of jarring or disturbing influences can break or confuse, while the water-supply lasts, or steam is kept up.

These injectors are non-lifting and lifting, as shown in the Figures 74 and 75.

Special attention is called to the important fact that by a recent improvement in the lifting injectors without increasing their cost or impairing their capacity to supply the boiler, they are enabled to lift water from the unprecedented depth of 25 to 28 feet if required.

Every injector is supplied with an overflow valve, which prevents air or dirt from entering the boiler.

Method of Working Lifting Injector.

Be sure the water valve or cock W is open; then

1st. Open the small jet valve J, with low pressure full, with high pressure partly, until the water flows out of the overflow at O.

2d. As soon as the water appears at the overflow, open the main steam valve S gradually, and close the small jet valve.

Should water still be discharged from the overflow, as may be the case where the steam pressure is low, reduce gradually the water-supply by the valve W until the discharge ceases.

To stop, close the main steam valve. This injector may also be used as a non-lifting where a head of water is available. While the injector is inactive the steam valve should be kept closed.

Method of Working Non-Lifting Injector.

To start, 1st. Open the steam valve S a little to let the condensed water in steam pipe out through the overflow O, and shut again as soon as clear steam appears.

2d. Open the water valve W.

3d. Open the steam valve S slowly, and the injector is working.

Should any water waste out of the overflow after the injector has started, reduce gradually the water-supply by the valve W until the discharge ceases.

To stop, close the steam valve S and the water valve W in the above-named order. Maximum temperature of water which the injector will feed, 140 degrees. The injector being at rest, the water valve W and the steam valve S should be kept closed.

General Instructions for Attaching Injectors.

1st. All the pipes, valves, and fittings must be of the full size to correspond with the number of the injector, as laid down in the table of capacities in the maker's catalogue; except when the water has to be draughted from a longer distance than ordinary, the suction pipe should be a size or more larger than the injector fittings call for.

2d. All joints and connections must be perfectly air-tight.

3d. A strainer should be fixed on the end of the water-supply pipe to prevent the admission to the

injector of foreign matter, such as chips, shavings, weeds and such like.

4th. A globe valve or steam cock is necessary on the steam supply pipe, between the boiler and injector, and a check valve and stop cock on the delivery pipe between the injector and boiler.

It is very necessary that the connections should have as few bends as possible and that the pipes invariably be round.

5th. That all pipes and connections must be blown out clean. This is of vital importance, as dirt and pipe cuttings cause nine-tenths of the leakage of new valves. The steam for the injector should be taken from the dome or top of the boiler.

CHAPTER VIII.

STEAM-ENGINE GOVERNORS.

For the complete regulation of an engine two things are necessary: first, a fly-wheel or heavy rotating body possessing inertia; and, secondly, a governor. The fly-wheel constitutes the most important and primary step towards the obtaining of uniform rotatory motion. It is a heavy wheel of cast-iron, with a massive rim, which becomes, as it were, a storehouse into which energy may be poured unequally during the passage of the piston from end to end of the cylinder, but from which it may be drawn out uniformly during the operation of driving the machinery. The object of the fly-wheel is to equalize the action of the force transmitted from the piston to the crank pin, and to confine any inequality within narrow limits of variation. But the fly-wheel alone is not sufficient for the purpose, since it is not only necessary to obtain a general uniformity of motion under the varying pressure of steam in the cylinder, but some method of adjusting the supply of steam itself is also required, whereby more power may be exerted when the resistance outside the engine increases, and less when the contrary happens.

The Regulation of an Engine.

It is with this latter object in view that the pendulum governor was invented. That instrument consists of a pair of heavy balls suspended from arms centred at or near a vertical axis and caused to rotate by the engine. If the power of the steam be in excess, the fly-wheel accelerates its motion, the balls fly outwards and move the lever of a throttle valve, so as to diminish the supply of steam; whereas, if

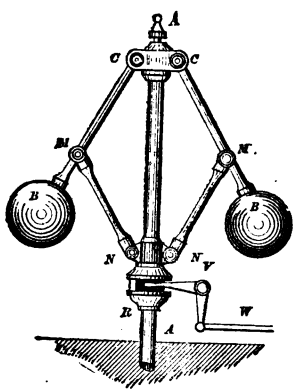


Fig. 76.

the power of the steam be in defect, the balls collapse and the throttle valve opens more widely. The apparatus is called a pendulum governor, because the time of a revolution is affected by the length of the axis of the cone formed during the rotation, in a manner analogous to that in which the time of oscil-

lation of an ordinary pendulum is affected by the length of the pendulum rod.

1. The common method of constructing the governor has been that shown in Fig. 76. The balls are suspended at the points C and C, a little on either side of the central vertical spindle A A. Each arm, as M M, is connected by a link to a sliding block N N. As the rate of rotation increases the balls fly out, N N rises, and in doing so actuates a lever which controls a steam valve and diminishes the supply of steam.

The effect of placing C and C at a little distance from the axis is to cause the variation in the height of the cone to become greater for any given rise of the balls, and thereby to render the governor less sensitive. The many defects of the governor just described have led to the invention and adoption of a number of improved types, some of which we will now illustrate and describe.

The Pickering Spring Governor.

When it becomes necessary to obtain results by the aid of mechanical appliances, that device which is the most simple in construction, most direct in its application and action, and most durable and economical in effect, is the most desirable one to secure.

The necessity for simplicity and direct action is nowhere more apparent than in the construction and application of the governor to the steam-engine; as, when, from usual or unusual causes, a variation is

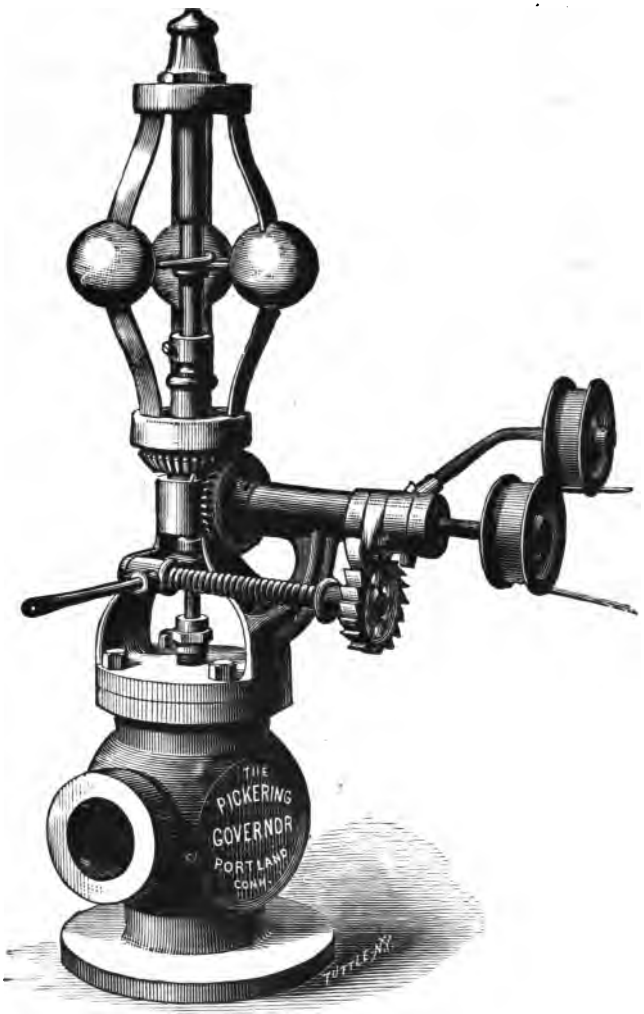


Fig. 77.—The Pickering Spring Governor. Page 266.

taking place in the amount of work being done, that governor which will the soonest adjust the steam valve to the new requirement will certainly be the one to keep the engine more nearly uniform in speed; thus reducing the total amount of steam needed, requiring less fuel, and insuring economy.

It is claimed that the extreme sensitiveness of the "Pickering" Governor—Fig. 77—with its great available centripetal force, causes it to fulfil the foregoing requirements. The reason of this is that the principles involved in its action are such that a mechanical movement is obtained without a joint, thus dispensing entirely with friction.

Another equally important arrangement is the combination of the balls and springs in such a manner that the comparatively slow movement produced by gravitation is entirely ignored, and in its stead the quick and sensitive action of simple but finely adjusted steel springs is obtained.

In order to fully appreciate this extreme sensitiveness, it is only necessary to attempt to maintain the tension of an ordinary "jig" saw by means of gravitation, say, a weight attached to a cord running over pulleys.

The law of gravitation is so completely ignored in the construction of this governor, that it will work equally well in either a vertical, inclined, horizontal, or inverted position.

The required centripetal force being entirely due to the tension of the springs, the valve is not carried

past the desired point by the momentum of heavy balls, as is the case when sudden variations take place in the amount of work being done by an engine supplied with the *old style* of governor.

All parts are made interchangeable, so that in case of accident parts may be sent by mail or express, with a certainty of their being correct.

After years of experience with various kinds of valves, the "balanced puppet" style has again been adopted as that which insures the most perfect equilibrium under varying pressures. As this kind of valve does not enter the seats, the troublesome effect of "sticking"—caused by unequal expansion—is avoided; and the valves and seats being made of special steam-metal, corrosion is entirely obviated; as is also the cutting effect so generally complained of as being produced by the current of steam when iron valves and seats are used.

It is often found desirable to change the working speed of an engine, even while in motion. A lever with movable weight is still applied by some governor makers for increasing resistance to the centrifugal exertion of the revolving balls. Now, this weight being actuated solely by gravitation, is guilty of the same objectionable sluggishness of action with which the heavy balls are charged; in fact, an otherwise sensitive governor would be injured by such a "hanger on."

In combination with the Pickering governor, the tension of a spiral spring is utilized for varying the

resistance to the centrifugal force of the balls; the tension being adjusted by means of a worm and worm-wheel, which may be manipulated *while the engine is in motion*, thus adjusting the speed according to the requirements.

The application of a simple device for detaching the valve from the governor, and allowing it to close so as to stop the engine in case the governor belt breaks, is an additional feature of security where an engine is in charge of a person careless enough to allow the belt to get out of order. As the driving-belt holds up by means of an idler pulley—tripping device—it cannot act except the belt breaks. This arrangement is very effective, but unnecessary where ordinary attention is given to the care of belts; a good belt well cared for will not break, and if flanged pulleys are used, the belt will not run off.

Previous to the recent improvements, this governor was well known among engineers in this country and in Europe, and we are informed is now making more friends than ever. Its introduction abroad is largely due to its exhibition at International Exhibitions. Specimens of it are to be found at most of the technical institutes of Europe, and the International Juries at Paris, 1867; Vienna, 1873; Philadelphia, 1876, and again at Paris in 1878, awarded this governor well-deserved recognition. Large numbers are in use in Great Britain; the well-known engineering firm, Joseph Evans & Sons, of Wolverhampton,

being the agents. It is manufactured at Portland, Connecticut, by T. R. Pickering & Co.

The Waters Engine Governor. (Fig. 78.)

A noticeable feature of this governor is that it can be run in any position, vertical, inverted or horizontal.

The governor is supported on a frame of novel design, which also closes the opening in upper end of valve chamber. The peculiar shape of this frame

Fig. 78.

admits of every access to stuffing-box, bolts, etc., even in the smallest sizes. Into this frame is fastened by a set screw a stud, which supports the casting composing the governor proper, and which is made to revolve around the stud. This casting is provided at the top with proper ears to receive the joints of the arms which revolve with it; also, at the lower end

with two projections, to which is bolted one end of a steel spring. The free end of this spring is formed into a slot, and also of such shape as to receive the ball which is secured to the spring by bolts. One end of the arm is formed into a small ball and fits loosely into the slot of the spring. The other end of the arm carries a piece of hardened steel, which works in a grooved composition collar, fitted to move up and down in the central stud. The valve stem is screwed through this collar and communicates motion directly to the valve, the balls being supported and rotated by the springs. All friction is taken off the joints of the arms, and the balls do not rise and fall by the rotation of the arm around its pivot, the slot in spring compensating for all difference in motion. The end of the valve stem is extended through the top of the composition collar and furnished with a handle with which to turn it, and a check-nut to hold it in place. Screwing this stem down causes the engine to run slower. Screwing it up causes it to run faster. The check-nut holds it wherever wanted. The bearing of the horizontal shaft is bolted to the frame, and if broken off by accident can be easily and cheaply replaced, without damage to other parts of the governor. All running surfaces are furnished with brass and steel washers.

It is claimed that no other engine governor has ever met with greater success or given more universal satisfaction in the same length of time than the "Waters." The company's sales have compelled them

to greatly increase their facilities for manufacturing, so that they are now able to fill all orders promptly. As they build governors and stop-valves only, and their machinery is specially adapted for that work, they are able to guarantee the best workmanship. All parts are made in duplicate and are interchangeable. The construction of this governor frees the joints of the arms from all friction and weight of the balls; the balls always revolve in the same plane without rising or falling, being supported by the springs, which replace the usual force of gravity. Its adjustable speed, which admits of the widest range of variation, is claimed to be superior to any other for close regulation, as a change of speed brings no extra resistance over the balls, and is not an extra charge as in the case of others. Having a valve of larger area than any other governor, light balls, springs and a medium high speed, it attains the highest degree of economy and closest regulation; and being extremely quick in its action, it is especially adapted to saw mills, rolling mills and flouring mills.

Edward Dewey & Co., successors to Chas. Waters & Co., Boston, Mass., are the makers.

The Chase Elemental Steam Governor,

As manufactured by the Chase Machine Company, Boston, Mass., was so named because the inventor aimed to produce a governor which, discarding all superfluous appendages, should apply *elemental principles* in the most simple and direct manner. The

centrifugal principle, like any other natural law, is absolutely invariable, and, provided it be not hampered by any clogging accessories, is perfectly suited to the requirements of a steam governor. All governors, centrifugal or otherwise, work on the principle of two opposing forces nearly balancing each other, and only a slight and feeble preponderance of power one way or the other to move the governor valve. The force available for the desired purpose being thus small though sure, it was reasoned that the best results could be obtained only by applying it to the valve directly, instead of through a train of jointed arms, swivels, valve-stems, etc. The chief things to hinder the accurate working of the governor being friction and lost motion, it is evident that these may be best avoided by dispensing with all go-betweens, and applying the moving power directly to the thing to be moved. An ordinary scale beam, consisting merely of a rigid bar with three nicely adjusted knife-edge bearings, is the perfection of accuracy, chiefly because it is the perfection of simplicity, and the steam governor, which resembles very closely the weighing scale, both in its working conditions and in its requirements, should realize as nearly as possible the same elemental simplicity. The Chase governor takes a short cut to these advantages by so arranging the governor valves that they themselves revolve about an axis, and are actuated immediately by the centrifugal force and the force of the spring, without the intervention of steam packed valve-stems, etc.

A new departure so radical necessitated the gradual working out of many details of practical construction about which there was no previous experience for a guide; but the correctness of the central principle proclaimed itself so unmistakably from the very outset, as to warrant much subsequent study in perfecting the details. It is now confidently believed that, as

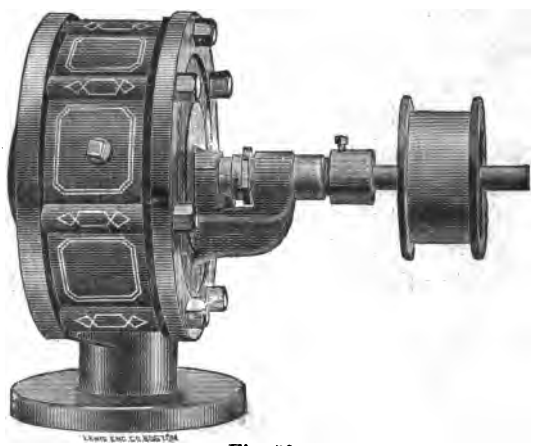


Fig. 79.

at present made, the simple theory of the machine is aptly matched by a common-sense simplicity of construction which will meet the approval of all intelligent critics.

Construction and Operation.

Fig. 79 gives an exterior view of the machine, showing simply a cylindrical case with one removable

head, from the middle of which projects a bearing to support the shaft for driving the governing mechanism inside. The adjustable screw-cap on the end of the bearing is for taking up the end play of the shaft. The gap in the bracket close to the cover contains a simple and convenient stuffing box. The square headed plug in the case is to be removed when necessary to adjust the speed. The inlet of the steam is on the side of the case opposite the driving shaft, and the outlet for the same at the bottom.

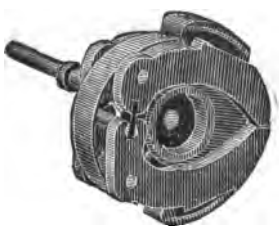


Fig. 80.—Ports of the governor entirely open.

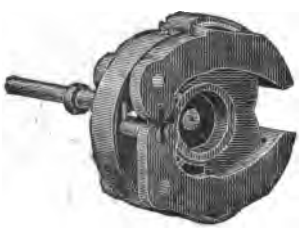


Fig. 81.—Shows the same partially closed.

The internal governing mechanism is shown in the three figures, 80, 81 and 82.

Fig. 82 is a view of the separate parts grouped together in their natural relative positions, and shows that this, the important part of the machine, consists of four principal pieces, viz.: a hollow revolving casting called a "flyer," a pair of centrifugal valves attached thereto, and a C spring.

The flyer is a chambered casting of irregular shape, into which the steam passes directly from the inlet

of the case. It is attached to and revolves with the driving shaft. It has two hollow arms in which, near their outer ends, are formed the governor ports, four in number, or two pairs. It also has two horns or projections to which the valves are pivoted.

The valves are two solid, box-shaped pieces of casting, each one having two plain interior faces opposite each other (balanced slide valves in fact), and they fit over the hollow arms in such a way that,

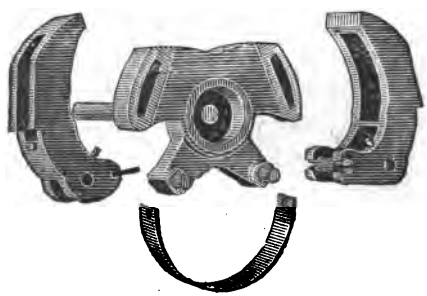


Fig. 82.

as they swing on their pivots, they cover or uncover the ports. It will be seen that these valves are "balanced" in a common sense way that is beyond dispute, and are entirely free from the uncertain action of double seated piston valves, most of which are affected more or less by the pressure and current of the steam. The valves are so hung as to get the best effect from the centrifugal force, which, as they revolve, throws them outward so as to cover the ports in the flyer. Also, the two valves

are connected by a knuckle joint so as to move together.

The edges of the valves, where they close the ports in the flyer, and the ports themselves are lined with hard composition metal, to resist steam cut.

The spring which draws the valves together, in opposition to the centrifugal force, is simply a broad strip of tempered steel of semi-circular or C shape. The matter of spring for this governor was a difficult one, both as to material and form, on account of the singular lack of positive knowledge among experts as to the capability of springs to resist steam heat without losing their elasticity or tenacity. Good authority recommended German silver as the only metal that would stand the necessary usage, and this did sufficiently well as to the elasticity, but was treacherous as to breakage, especially in the larger sizes. Hence recourse was had to tempered steel, and long experience has now proved this material to be the best for springs, whether in steam or out of it. Steel springs retain their elasticity perfectly in steam, and are less liable to break in that condition than otherwise. Moreover this C spring, embracing as it does the outside of the flyer and valves, is of such proportions in comparison with its duty, as to put breakage out of the question.

In connection with the C spring is a device for changing the speed. The spring is attached to the valves by means of holes near its ends, which fit over the heads of screw studs in the valves, so that by

turning the screws outward (with a screw driver) the spring is tightened and the speed increased, and *vice versa*. A screw-plug in the case is removed to reach the adjusting screws. This method is sufficiently convenient for all practical purposes, being a matter of a few minutes when the engine is stopped; and is sufficiently *inconvenient* to prevent constant and needless tampering with the speed while the engine is in motion.

An important improvement has been made in the manner of transmitting the steam into the revolving flyer without leakage. The inlet in the middle of the flyer is surrounded by a slightly raised rim or hub, as seen in the cuts. This hub abuts against and runs in contact with a corresponding stationary hub projecting from the interior of the case, and the contact of the two hubs is regulated by an adjustable thrust bearing on the shaft outside. The steam pressure tends to separate the two bearing surfaces, thus avoiding the friction and wear of the packing-ring formerly used. Consequently the machine runs much easier than before, and any possible leakage from wear is under perfect control.

Some of the theoretical advantages at which the Chase governor aims, and which the severest tests are claimed to have amply established, are as follows:

1st. There is no valve-stem, with its attendant friction of steam packing. People who think this of no consequence forget that the actual valve-moving power of a governor is as slight as that of a scale

beam in equilibrium, or the pendulum of a clock. How would these latter machines work with a stuffing-box attachment? Moreover all valve-stems were smaller where they worked in the packing, and consequently bring up against a shoulder and go hard just as the valve closes, the very place where they ought to go the easiest.

2d. Another unavoidable difficulty with the valve-stem is the unbalanced steam pressure, which tends to force it out of the valve-chamber in opposition to the action of the governor balls, thus putting upon the latter an uncertain and variable duty. Besides this, all steam-chest pressure is of an intermittent, throbbing character, owing to the cut-off action of the slide valve, and this throbbing pressure, communicated through the valve-stem to the balls, accounts for much of the mysterious churning and pumping in governors otherwise well-conditioned.

3d. In the Chase governor it is claimed that there can be no lost motion or wear that will affect its governing qualities. All superfluous joints are avoided, especially the troublesome necessity of connecting a pair of revolving balls with a non-revolving valve-stem. Lost motion resulting from wear or careless workmanship destroys one of the chief requisites of a good governor, viz.: its capability of responding to *very slight changes* in speed. The Chase governor, with its centrifugal stemless valves and spring attached directly thereto, avoids the whole difficulty at a single stride.

The Allen Governor.

The Allen steam engine governor (Fig. 83) has achieved considerable success in controlling and regulating almost all kinds of link motion and variable cut-off steam-engines, including the Corliss (to which it is specially adapted), and all other engines subject to great variations. It is claimed that every engine to which it is attached will run with the throttle wide open. To whatever changes in steam pressure, or changes however sudden, in power used, the engine may be subjected, with this governor, it should not vary more than one revolution as long as there is sufficient steam to do the work.

This governor is simple in construction, not liable to get out of order, permits the speed of the engine to be changed at will, is neat in appearance, noiseless, very durable, saves the engineer's time, saves fuel, and is powerful and sensitive in its operation.

The construction of Allen's governor is as follows:

Within a corrugated cylinder, which has small projecting ribs on its interior periphery, and which is partially filled with oil, a paddle-wheel is caused to revolve by a spindle passing through one end of the cylinder, driven by a belt communicating with the fly-wheel shaft. The tendency of the revolving paddle-wheel is to cause the cylinder to move in the same direction. On the opposite side to the revolving spindle is a trunnion or short spindle fixed to the cylinder, attached to which is a wheel carrying a set of movable weights suspended by a chain, the speed

of the engine being regulated by the number of weights. Attached to the wheel, and keyed on the end of a short spindle, is a pinion revolving with the cylinder, and working in a toothed sector, the arm of which, being fixed on the spindle of the throttle-valve, opens or closes it as the oil cylinder moves with the paddle, according to the variation of load thrown on the engine. When used with a variable

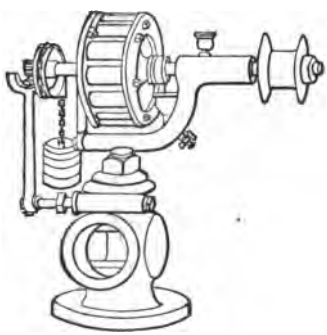


Fig. 83.—The Allen Governor.

cut-off engine, the arm is attached direct to the cut-off.

It will be seen that the weights are raised and lowered in a nearly vertical line, and, unlike those of some other governors, remain the same at every point of their suspension. The high rate of speed used acts advantageously in making the governor very sensitive; and, all parts being lubricated, it works with the smallest amount of friction. The centrifugal or ball principle being entirely abandoned, the movable

weights are suspended as easily at one point as at another, by the action of the paddle-wheel in the oil cylinder.

The peculiar action of this governor, which enables the use of a valve of large area, thereby admitting to the engine cylinder the greatest possible boiler pressure at each stroke of the piston, has produced excellent results by being attached to old engines. In running an engine with this governor, with high or low pressure of steam, and with all variations of power, the throttle is opened wide in the morning, and remains so until closed at night, thus relieving the engineer from all labor and care, except keeping the engine oiled, and giving him a great deal of time for other duties.

Allen's governor valve is constructed with a double disc in a tubular form, and is perfectly balanced, there being no spindle, as in the ordinary throttle valve, to interfere with its equilibrium. The valve is moved by means of a lever, and is opened and closed by a rocking motion of a steel spindle, which is covered with brass, ensuring the greatest possible durability. The Allen Governor Co., Boston, Mass., are the manufacturers.

CHAPTER IX.

THE STEAM-ENGINE INDICATOR.

THE steam-engine indicator is designed to register automatically upon paper the pressure of steam in the cylinder at every point of the piston's stroke. The form of the diagram thus drawn by it affords information of a variety of facts not otherwise readily obtained. It must be remembered, however, that it tells nothing about the causes which have determined the form of the figure which is described; the operator concludes what these are by a process of reasoning based upon observation and experience and some given data; errors are here very liable to be committed, and the ability to arrive at accurate conclusions is of the greatest importance, and one of the highest attainments of an engineer. It is now universally conceded that the indicator is an invaluable appendage to the steam-engine, and when successfully applied and intelligently read, cannot be too highly estimated. The good condition and economy of every engine made or sold ought to be proved by the indicator diagram. In fact, no builders of first-class engines consider their canvass complete without showing a fac-simile of the diagram of their engine. The advantage resulting from the use of this instru-

ment, in point of economy, safety and power, is very great, and is recognized by the master mechanics and engineers throughout the country.

History of the Indicator.

The invention of the steam-engine indicator (Fig. 84) is accredited to James Watt. It has undergone

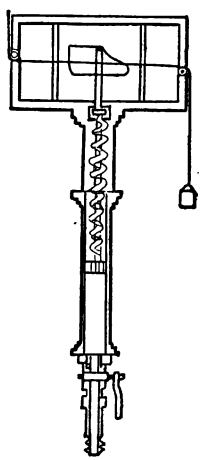


Fig. 84.—Watt's Indicator.

various modifications and improvements since his time. It was at first direct-acting, or, in other words, the pencil was attached directly to the piston-rod, and registered the motion of the same without multiplication, and was only adapted for slow-running engines. In this form it attained its highest point of excellence as manufactured by William McNaught, of Scotland. (See Fig. 85.) The adoption of in-

creased velocities of piston, with greater pressures of steam and higher grades of expansion, caused the long and tremulous spring used to oscillate violently by the momentum of the piston and its connections, and gave as a result a serrated figure, from which but little information could be extracted. At this time an improved steam-engine indicator was invented by Charles B. Richards. This indicator had a short, strong spring, short motion of piston, combined with a lever and links for multiplying the motion of the piston and transmitting it to the pencil. These were the distinguishing features, and were designed to obviate the difficulties before mentioned, but it was found still subject to grave errors of registration. The multiplication of the motion of the piston was not uniform for all portions of the stroke; the line of motion of

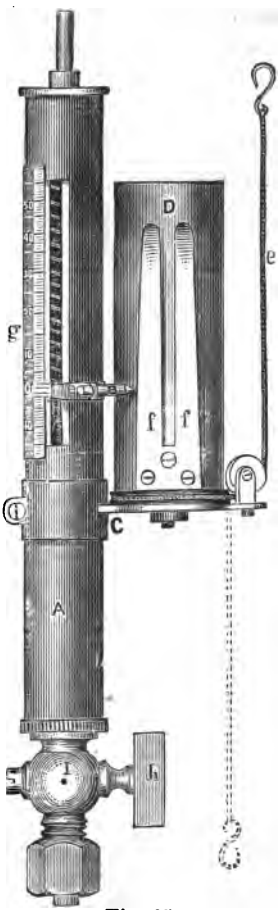


Fig. 85.

the pencil was not strictly parallel with the line of motion of the piston, describing not a straight line, but only an elongated S. But it was a great stride in the right direction, and answered in the absence of anything better, until the still increasing velocities of piston outstripped its capacity to register without serrated lines. This last fault, with its other defects, made it imperative that a more reliable instrument should be made before correct indications could be procured.

After considerable study and experiment, Mr. Crosby invented the improved parallel motion steam-engine indicator, which obviates the above difficulties to a great extent, and superiority is claimed for this instrument for engines running at any velocity.

Description of the Crosby Indicator. (Fig. 86.)

The principle and action of indicators are so simple, and to most practical engineers now so well understood, that it will only be necessary to give the following cut and description of the parts of this instrument to readily appreciate the advantages accruing from its use:

A is a case or jacket enclosing a cylinder, into which a piston is nicely fitted to move without friction; to the upper side of this piston is attached a steel helical spring, the upper end of which is fastened to the cap or head of the cylinder; to the upper end of the piston-rod B is directly jointed the short lever C D, whose short end is jointed to the

head of a vibrating standard at D, and its long end is jointed to the long lever E F at the point C. The long arm of the lever E F is jointed at its outer extremity

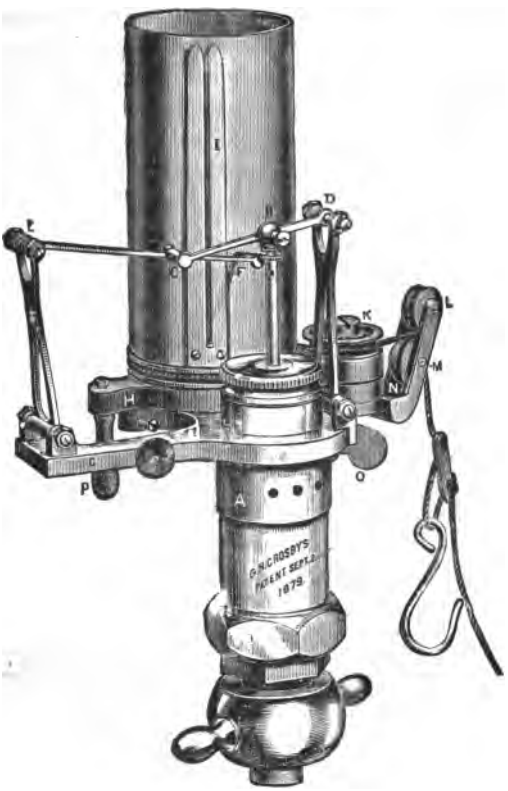


Fig. 86.—The Crosby Steam-Engine Indicator.

to a second vibrating standard at E, and to the other extremity is attached the pencil F. To the case A is

permanently attached the horizontal plate G, at one end of which is jointed a corresponding plate H, situated above the former and carrying the revolving drum, covered by the paper cylinder I. To this drum is attached a cord, wound around a groove at its base and carried by the guide wheel K, between the two extra guide wheels L and M; the guide wheels L and M are attached to the arm N, which swivels around a point in line with the axis of guide wheel K, and is held in its proper position by the thumb-nut O. The drum carrying the paper cylinder I is rotated in one direction by the tension on the cord, and in the reverse direction by the reaction of a spring enclosed therein; the tension upon this spring may be adjusted to suit by the thumb-nut at the open end of the drum. The plate H, carrying the drum and paper cylinder, is held away from the pencil F by a spring situated between the plates H and G, directly in line with the axis of the drum, until the operator desires to take a diagram. By pressing upon the handle P the paper cylinder is moved forward, and the pencil comes in contact with the paper. Immediately upon removing this pressure, the paper cylinder automatically assumes its former position. Two adjustable stops determine the amount of this motion and regulate the force with which the pencil presses upon the paper, a hair line being attainable without friction. The bushing which carries the pencil is bored to receive a graphite or metallic wire, and is supplied with means for holding it in any po-

sition desired. The piston-rod is bored at each end almost half its length, leaving a thin partition or stop in the centre; the upper chamber is used as a reservoir for a lubricant, and is provided with pin-holes close to the partition to allow the oil to flow out and down, and so lubricate the rod and piston; the lower chamber allows the steam to enter and warm the lubricant, causing it to assume a more limpid form and flow freely in cold weather. The piston-rod is thus made lighter without weakening it materially. A minute portion of felt placed at the bottom of the reservoir will prevent the oil from flowing too readily. It can be filled at the cross-head with a few drops of oil, by using a common pressure-oiler with a very small nozzle. To adjust the pencil to the proper position for springs of different scales, the head of the piston-rod is provided with a screw-threaded sleeve and lock-nut, by means of which the pencil may be made to assume any desired height. If it is wished, the guide wheels, etc., may be removed to the opposite end of the plates H and G. The use of a revolving drum for transmitting motion to the paper having been demonstrated to be the best means for the purpose, it has been adopted; the only pre-requisites being sufficient strength of spring and inelasticity of cord to overcome the momentum of the reciprocating parts. In any other devices, such as require a connecting-rod, there is imparted to the latter a tremulous and excessive motion, caused by its length and weight running at high speed when

connected with a vibrating arm, which is transmitted to the lines of the diagram, thus producing error.

The greatest degree of accuracy and excellence is maintained in the manufacture of this instrument, and if properly connected and operated its indications may be relied upon implicitly.

The advantages in using this indicator are numerous, and a few of the most obvious need only be mentioned.

1st. The motion of the pencil is a uniform multiplication of the piston motion.

2d. The parallel motion is a *true* parallel and not a geometrical approximation.

3d. The weight of the reciprocating parts is greatly reduced.

4th. The parts which require the most lubricating, viz., the cylinder, piston and rod, are automatically oiled.

5th. The pencil, instead of projecting beyond the piston-rod several inches, is directly behind the piston-rod, only about one-quarter of an inch.

6th. It is more easily operated. With former indicators it was necessary to be an expert (to some extent), with a delicate sense of touch, to determine just the proper force to move the pencil against the paper, so not to tear it or cause undue friction. Now in this indicator all this is predetermined, and is so nicely adjusted that a child can operate two indicators —one on each end of the engine cylinder—simultaneously, without the slightest difficulty, and obtain hair lines without friction.

7th. This instrument can be used right or left-handed, by simply removing the guide-wheels, etc., to the opposite end of the plates.

To adapt the indicator to any pressure, springs are made of the following scales:

Nos. —	8	12	16	20	24	30	40	50	60	80	100
Lbs.—	24	36	48	60	70	90	120	150	180	240	300

The number of the spring represents the pounds per square inch required to compress it sufficiently to move the pencil vertically one inch on the diagram. The figures in the lower line designate the maximum pressure of steam or steam and vacuum, which, together with space allowed at each end of stroke for adjustment, equals the whole distance which the pencil can travel.

What can be Ascertained by the use of this Indicator.

1st. Whether the steam passages from the boiler to the cylinder are of sufficient size to supply steam in time to produce the best results; and what proportion of the boiler pressure is utilized.

2d. Whether the discharge passages from the cylinder are of sufficient size to relieve properly; and, if not, how much remains as counter-pressure.

3d. Whether the piston is properly fitted; or allows steam to escape into the exhaust.

4th. What pressure of steam there is on the piston at every position in the cylinder; as well as its average.

5th. At what point in the stroke, and at what pressure the steam is cut off; and whether it is cut off sharply or is wire-drawn.

6th. At what pressure the steam is finally released.

7th. How soon in the stroke the highest pressure is reached; and how well maintained.

8th. The amount of vacuum acting upon the piston of a condensing engine at every point in the stroke; and its average.

9th. Whether there is any compression of the steam remaining in the cylinder before the stroke commences; and, if so, where it begins and how high it rises.

10th. The actual consumption of steam in giving motion to the engine alone; and also what additional steam is used in giving motion to the shafting or the machinery attached.

11th. Where power is sold, how much each tenant consumes; and in large establishments, where friction of shafting and machinery forms a large proportion of the resistance offered, it guides in the selection of proper lubricants.

12th. The economy of using high pressure steam and expansion; and the relative efficiency of the different apparatus for procuring expansion.

13th. The quantity of water that would under given circumstances be most economically used in the condensation of the steam, if attached to the air-pump of condensing engines.

14th. The accuracy of the steam gauge when applied correspondingly.

15th. Whether the valves are properly adjusted and in good condition or not.

The Crosby Steam-Engine High Speed Indicator.

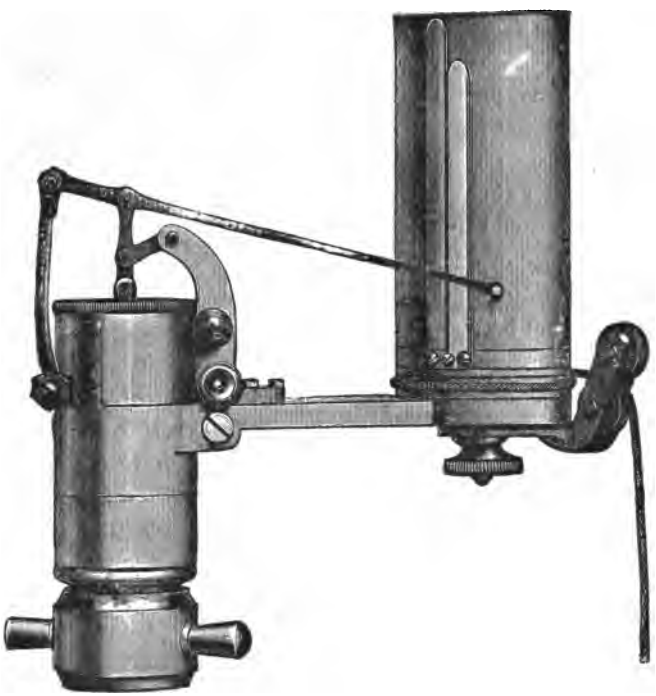


Fig. 87.

This instrument (Fig. 87) is designed more expressly for indicating engines of the highest speed

and accomplishes the purpose fully. Every part of the instrument is reduced to the utmost extent compatible with precision, and the whole so arranged and combined as to give the most accurate results.

Directions for Using the Crosby Indicator.

How to attach it.—The indicator should be connected as closely to the cylinder of the engine as possible, as pressure is lost by the use of pipes. The connection may be made by drilling the cylinder or its heads; but care should be used in drilling the cylinder that the piston does not cover the hole when at the end of the stroke. By allowing a small quantity of steam to enter the cylinder as the drill begins to go through, all chips will be blown out. No lead or putty should be used in making the connections. Keep clear of the thoroughfares, as steam passing the hole for the connection reduces the pressure in the indicator; screw the stop-cock to its place, then open it and blow steam through to clear the connections, and attach the indicator by means of the union nut, when in the best position to operate; move the adjustable guide wheels to the best position for receiving the cord, and then connect the cord to the apparatus for transmitting the motion from the engine to the paper. The cord must be connected with some part of the engine having a movement co-incident with the piston, and which would give the paper cylinder a movement of about three-fourths of a revolution; it will frequently be found necessary to

erect a temporary rocker-shaft, or lever connecting with the cross-head, for reducing the motion; for a beam-engine, a point on the parallel bar, beam, or beam-centre will answer. Beyond these suggestions, the ingenuity and judgment of the operator must determine what is required to produce the proper movement. Care should be taken that the cord be so led off from the part which gives it motion that when the engine is on half-stroke it will be at right angles to such part; but between the first pulley and the indicator it may take any required direction. Use as few pulleys and as short a cord as possible. It is also necessary that the length of the cord be easily adjusted

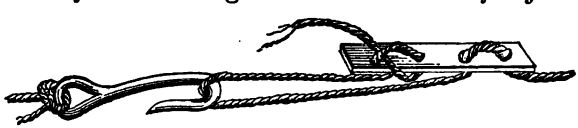


Fig. 88.

and readily connected and disconnected. To meet these requirements, one end should be provided with a running loop and hook (see Fig. 88). Arrange the motion of the paper cylinder, by means of the running loop, so that it shall not be checked at one end of the stroke by the stop fixture, and thereby slacken the cord; nor at the other end by the springs for holding the paper on the cylinder, coming in contact with the pencil; either of which would render the diagram useless.

How to take a diagram.—Remove the paper cylinder from the drum and place the paper upon it; the easiest method of doing this is to secure the two

lower corners of the paper between the thumb and finger, then put the loop so made over the top of the cylinder; slip the edges under the springs and slide the whole down to the bottom, leaving it smooth and tight.

Return the cylinder to the drum; adjust the cylinder to the pencil for a hair line; open the stop-cock and allow the steam to enter, heat and expand the cylinder to give freedom of motion, then turn the T handle of the cock-plug to a horizontal position to allow of atmospheric pressure *under* the piston as well as above it; connect the cord and draw the atmospheric line; then turn the T handle to a vertical position and press the paper cylinder up to the pencil, by means of the handle P, long enough for the engine to make one revolution. No nicety is required in this, as the adjustable stop determines the distance moved and delicacy of the lines drawn. The engine should be allowed to run a short time before taking diagrams, to clear the cylinder from water and thoroughly heat it.

If it is a new indicator, allow its piston to work for a few moments before taking a diagram. After a diagram is taken, disconnect the cord by means of the hook and close the stop-cock, as continual working only wears out the instrument needlessly. Remove the paper and make the proper memoranda upon the back *at once;* this should at least include the following particulars, viz.: description of engine, scale or spring, diameter of cylinder and piston-rod, which

end of cylinder, length of stroke, number of revolu-

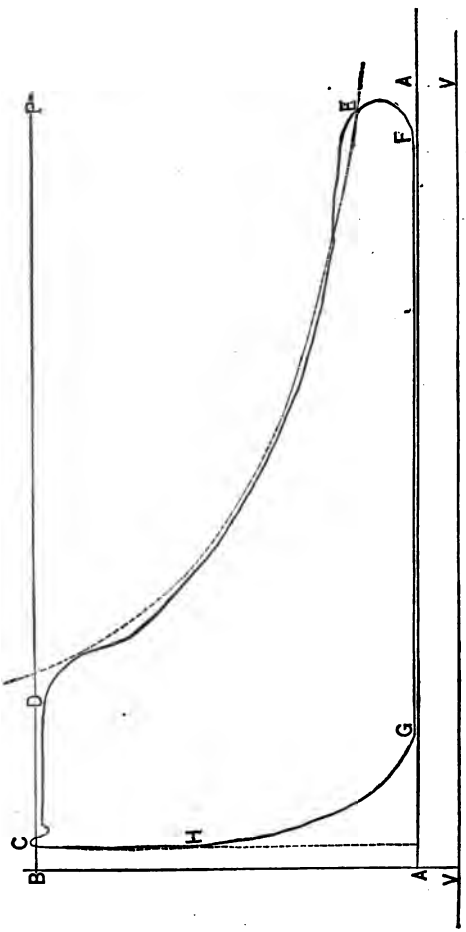


Fig. 89.—Cylinder 7½x10. 230 revolutions. 136 lbs. steam, 68 scale. Automatic cut-off. Crosby Indicator.

tions per minute, cubic contents of clearance and

thoroughfares, pressure of steam in the boiler, and, if a condensing engine, the vacuum indicated by the gauge. As many more particulars and circumstances should be added as can be readily ascertained, among which it is well to include the length of connecting-rod and the weight of all the reciprocating parts.

To avoid mistakes, designate the two ends of the cylinder as *out-end* and *crank-end.*

How to take apart and clean it.—Immediately after using the indicator it should be properly cleaned and oiled. This is done by disconnecting the short lever at the points B and C; then unscrew the cap or head of the cylinder and carefully remove the piston and spring; empty the cylinder of water and clean and dry all the parts; lubricate the cylinder, joints and journals, with a very small quantity of oil, which must be free from all impurities—porpoise or watch oil is the best; never unscrew the rod from the piston. If the inner surface of the cylinder or the piston should get scratched by any means (and it will be detected by the unsteady lines of the diagram) it should be remedied at once, and in this manner: When the instrument is apart, cleaned and oiled, the piston may be replaced in the cylinder without the spring; screw on the cap or cylinder-head for a guide and then revolve the piston-rod between the thumb and finger, at the same time moving it up and down; remove it occasionally and wipe all the parts clean; after a few operations the surfaces will wear themselves smooth. No grinding or polishing

should ever be resorted to. When the parts are clean

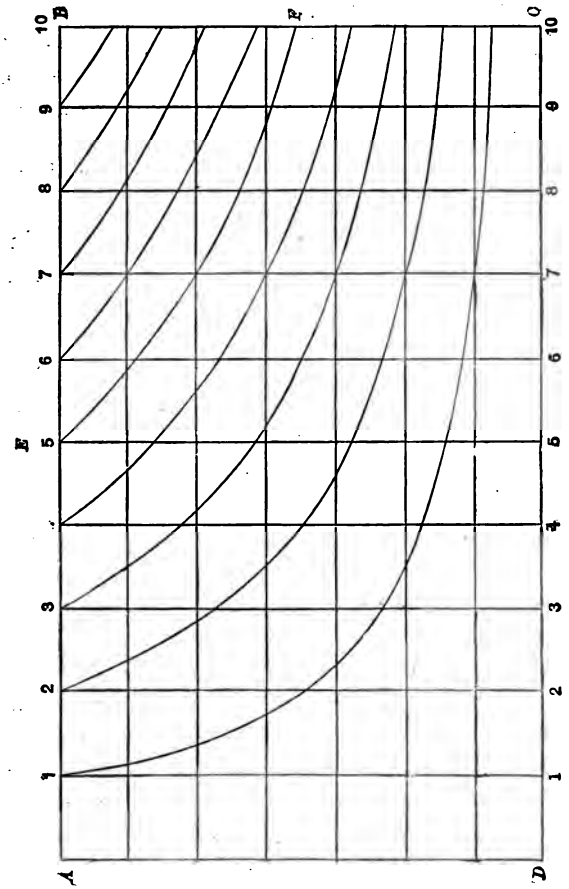


Fig. 90.

and the cylinder plumb, the piston, with spring removed, should move freely and uniformly, but

slowly, through the whole length of the stroke, with the levers attached and the cock closed; with the cock open it should drop freely from any position. In putting the parts together the levers and standards should be tested to see if they move freely of their own weight and without side motion in the joints; then securely screw the spring to the piston and cap. Care should be taken that the slot in the head of the piston-rod is in line with the lever when making connection, otherwise it would bind and cause friction.

Diagrams.

It must always be remembered that the indicator's office is only to represent the pressure on the piston at each point of the stroke, by lines circumscribed upon paper. The correct reading of these lines is left entirely to the operator. For the mere purpose of ascertaining the condition of the valves, piston, etc., it will be quite sufficient to scan the outlines of the diagram; but if the power of the engine is required, the mean pressures upon the opposite sides of the piston must be ascertained by measurement. In using a graphite wire for marking the lines, any paper susceptible of taking a fine impression from an ordinary lead pencil will answer, but if the metallic point is used, a paper expressly prepared for the purpose is necessary, and will be furnished upon application. The impression in this instance is indelible.

Diagrams should be taken from both ends of the

cylinder, and simultaneously, if practicable; and the mean result of the two taken as a basis for estimating the power of the engine.

The common idea that if the valves are properly adjusted, two diagrams thus taken must be alike, is a mistake. They will in some respects be dissimilar, from various causes, one of which is the difference in the speed of the piston at opposite ends of the stroke. (See Fig. 95). There may be a difference also in the size of the thoroughfares. The extreme ends of the diagram are produced at the exact time the engine is passing its centres. In diagrams of non-condensing engines, the lower line is usually drawn slightly above the atmospheric pressure (see Fig. 89).

Explanation of Lines of Diagrams.

For convenience in describing diagrams their several parts will be indicated as follows:

Atmospheric Line,	AA.
Clearance Line,	AB.
Boiler Pressure Line,	BP.
Admission Line,	HC.
Steam Line,	CD.
Point of Cut-off,	D.
Expansion Curve,	DE.
Point of Exhaust,	E.
Exhaust Line,	EF.
Counter Pressure Line,	FG.
Compression Curve,	GH.
Vacuum Line,	VV.
Theoretic Curve,	Dotted Line.

(See Fig. 89.)

In condensing engines consider line EFG as all exhaust. (See Fig. 89.)

Different engines give different diagrams, and

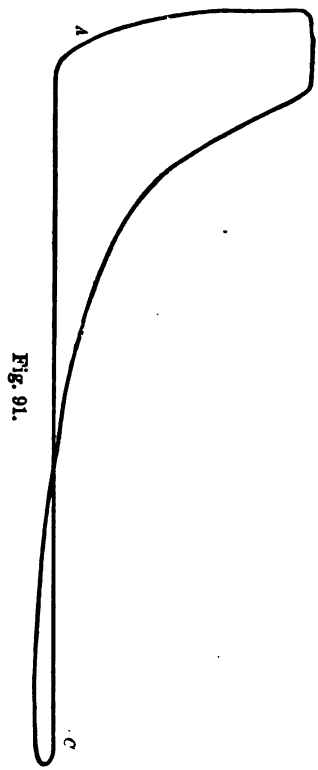


Fig. 91.

diagrams taken from the same engine under different circumstances differ. On account of the diversity of style of engines, and the attending variety of circum-

stances and surroundings, no design for a perfect diagram will answer for more than one particular engine, and then only with one particular combination of conditions, as every change, whether of speed, pressure, friction, work, etc., produces different results. The important thing always is to procure the greatest mean effective pressure with the lowest terminal pressure. But a few general rules may apply. By taking the different lines drawn by the indicator, in succession, commencing with the stroke, the main features of merit or defect may be pointed out. For convenience to the beginner, however, all the lines of the diagram will be noticed and explained in the usual order of production.

The Atmospheric Line is traced when the atmosphere has free access to both sides of the piston of the indicator before steam is admitted, and indicates the line of atmospheric pressure, or zero, on the steam gauge. The following lines are automatically traced by the indicator and are described as follows:

The Admission Line represents the rise of pressure due to the admission of steam to the cylinder. If it is at right angles to the atmospheric line, and is not curved or inclined forwards where conjoining with the steam line, it indicates that full pressure is exerted upon the piston at the commencement of the stroke, caused either by the quick entrance of steam, or by compression, or by both combined. Should this line incline forwards and form a curve in connecting with the steam line, the reverse is indicated; or should

this line continue vertically beyond, and then sud-

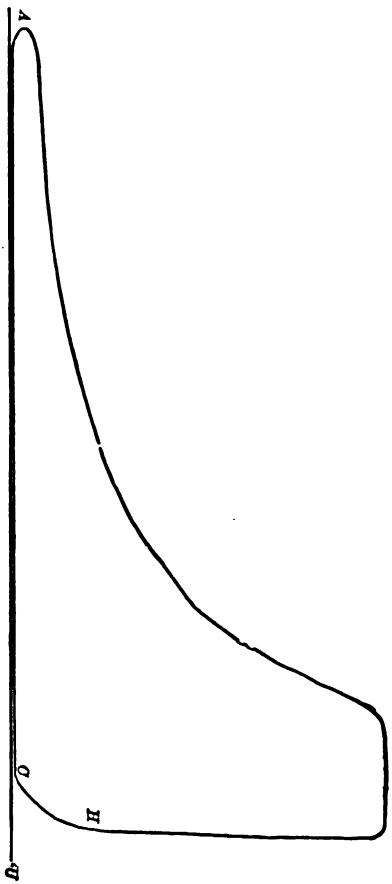


Fig. 92.

denly drop to the level of the steam line, it signifies that the steam is wire-drawn and cannot enter the

cylinder with freedom sufficient to keep up the full pressure as the piston starts forward; but should this line, after projecting above, be suddenly depressed below the level of the steam line, vibrating back and forth one or more times on the latter line with acute angles of return, it may be attributed to the momentum of the reciprocating ports of the indicator while running at very high speed. (See Fig. 94.)

The Steam Line represents the pressure of the steam upon the piston and its duration while acting directly, that is, being constantly reinforced, from the boiler; and shows what proportion of boiler pressure is attained, and how soon, and how well maintained. Should this line dip below a horizontal it is an indication of either wire-drawing of the steam somewhere between the boiler and the cylinder, or loss of steam from some cause, such as leakage around the piston, or condensation of steam on entering the cylinder from loss of heat by radiation and condensation, internal and external. It also shows at its termination the point at which the valve closes or steam is cut off.

The Expansion Line commences at the point of cut-off where the steam line ends, and represents the fall of the pressure due to the expansion of steam remaining in the cylinder after cut-off. The nearer this line corresponds to the theoretic expansion curve the better; but it generally runs somewhat above, as the piston continues on its course. This is caused partly by leakage of the valve. Should this line,

after falling considerably, begin to rise again, and show before the termination of the stroke a pressure

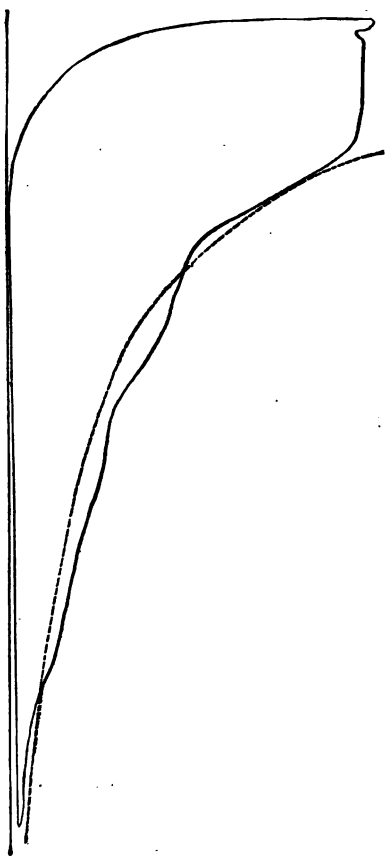


Fig. 93.—Cylinder 7½x10. 230 revolutions. 56 scale. Boiler pressure, 105 lbs. Automatic cut-off. Crosby Indicator.

in excess of what it did at some preceding point, it indicates that re-evaporation of the moist steam has

taken place. The heat for this purpose is supplied by the surfaces of the cylinder and piston in contact with the steam, and must be regained at the beginning of the next stroke from the direct steam. The excess or rise of the line measures the heat lost in the process. Where the expansion curve intersects the steam line there is the point of cut-off; it is clearly defined where the valve closes quickly (see Fig. 92), but where it closes slowly it is more difficult to locate; in the latter case, take the point on the curvature where it changes from convex to concave, and through it extend the expansion curve upwards by the eye until it cuts the steam line; the point of intersection is the apparent cut-off. (See Fig. 89.) Should the expansion line drop below the true curve, it indicates, in a non-condensing engine, that the piston leaks, or that condensation has taken place; in a condensing engine, that either the piston or the exhaust valve leaks. Should this line fall below the atmospheric line (see Fig. 91) the area thus enclosed should be measured and deducted from the impelling pressure, as it represents counter-pressure or power lost.

The steam may be cut off so early that expansion cannot be advantageously employed, even with the highest pressure. If this line is *wavy*, consequent upon extreme speed and pressure and the use of a spring worked at its utmost capacity, or should the pencil describe several diagrams before removal, the average or mean should be ascertained.

The Exhaust Line commences where the expansion

line ends, and is traced while the excess of pressure remaining at the point of exhaust is being released. It indicates whether the exhaust valve opens properly or not, and whether the exhaust port and passages are of sufficient size for the free exit of the steam.

The Line of Counter-pressure in a non-condensing engine represents by its distance above the atmospheric line the pressure in front of the piston during the return stroke. (See Fig. 89.) Its presence, to any considerable degree, indicates one or more defects, such as smallness of exhaust port or pipes, leakage of piston or valves, etc.

The Compression Line, when it exists, represents the rise of pressure due to the compression of the steam shut in the cylinder by closure of the exhaust, and indicates the point on the return stroke at which the exhaust valve closed and compression commenced, and the amount of pressure resisting the movement of the piston as it nears the end of the stroke. (See Figs. 89, 92, and 93.) This pressure is called "cushioning," and should be calculated and deducted from the impelling pressure. Should this line be projected above the boiler-pressure, then suddenly drop in nearly a perpendicular line to the level of the steam line, thus forming a loop, it indicates an excess of compression due to closing the exhaust too soon.

The remaining lines are drawn by the operator, and are described as follows:

Boiler Pressure Line is drawn when the engine is blocked, so that the full pressure on the boiler can act

upon the Indicator, thereby testing the steam gauge, or it may be drawn by scale, at a distance from the atmospheric line equal to the pounds pressure per square inch as shown by the steam gauge, if this is

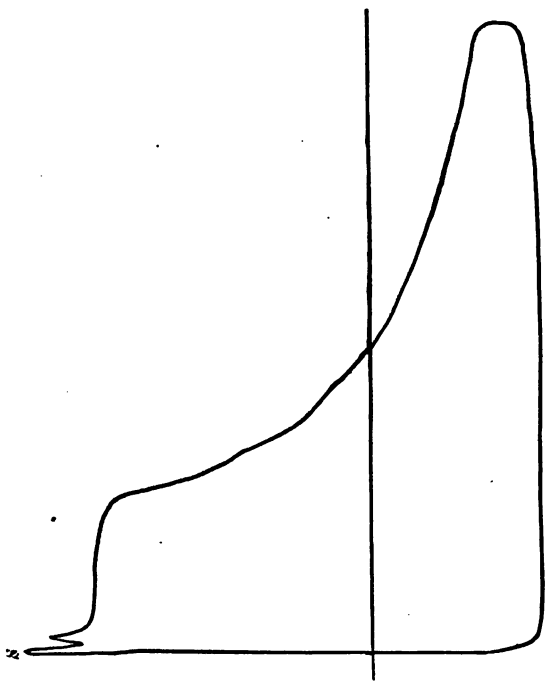


Fig. 94.

known to be correct. This line shows by comparison with the steam line the amount of pressure in boiler not utilized by the engine.

The Vacuum Line is laid down by scale, usually 15. pounds below the atmospheric line, but 14.7 is

nearer correct, and represents perfect vacuum or absence of all pressure.

The Clearance Line is laid off a certain distance from the steam end of the diagram, which distance is to the whole length of the diagram as the total volume of clearance, including ports, is to the piston displacement. It represents the waste room between the cut-off valve and piston when the latter is at this end of the stroke, and is found by either calculating or actually measuring by water the cubic inches contained in the space between the piston and cover when the engine is on its centre, and that of the ports and passage ways back to the valve; divide by this the solid contents of that portion of the cylinder occupied by the stroke of piston, and the quotient will represent the denominator of a fraction, which with *one* for a numerator will give the proportional part of the length of the diagram to be added to the steam end thereof. (See Fig. 89.) Through the point thus formed draw a line at right angles to the atmospheric line. When the clearance is taken into account, this space must be reckoned as part of the diagram in calculating the average pressure, and in producing the theoretic curve, or line of perfect expansion.

The Theoretic Curve represents the line of true expansion, or isothermal line, and shows by comparison with the line of expansion drawn by the Indicator the degree of excellence attained in regard to the construction, adjustment and working of valves, fitting of piston, protection of the cylinder, and efficiency of apparatus for procuring expansion.

According to the law of expansion, if a perfect gas enters freely to the cylinder while the piston is travelling a distance equal to one of the above divisions (see Fig. 90), and is then cut off and the piston continues on to the next division, supposing the gas to remain at the same temperature, the pressure is reduced one-half; continue the piston to the third and it will be reduced to one-third; if to the fourth, to one-fourth; and so on to the end of the stroke.

This line should always be drawn after the diagram is taken, so that the expansion line actually produced may be compared therewith. If the valves are properly constructed and adjusted, the piston properly fitted, and the cylinder sufficiently protected, or *jacketed*, these two curves should nearly coincide—the nearer the better. The true curve commences on the steam line at the point of cut-off, and terminates at the end of the stroke. It may be ascertained in the following manner:

Let an area be supposed (see Fig. 90) whose length represents the stroke of the engine and clearance, and whose breadth represents ninety pounds of steam pressure above the atmosphere, scale forty pounds to the inch. Draw the line of perfect vacuum C D; divide the whole area into any number of equal divisions, by drawing lines (ordinates) at right angles to the vacuum line, and have one of these lines pass through the point of cut-off; number these lines in the direction of stroke, 1, 2, 3, 4, etc. Take the number of the line at the point of cut-off for a nu-

merator and the number of the next line for a denominator, and this fraction will, by measuring from the vacuum line, determine the point on this next line, through which the theoretic curve passes. Con-

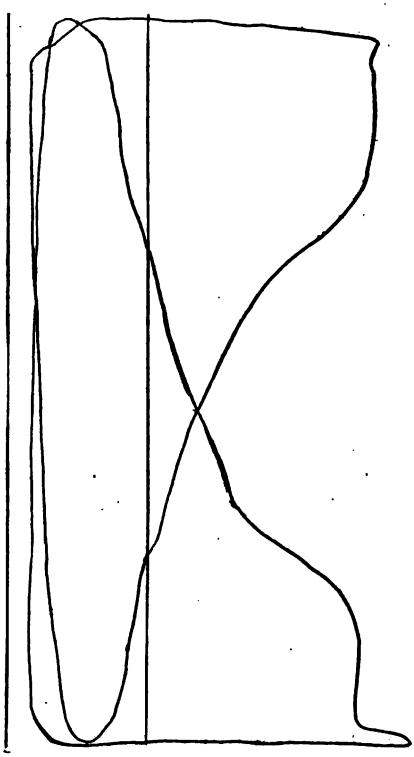


Fig. 95.

tinue in this way through the whole number of lines; then connect these points by lines drawn sufficiently curved to make the whole curve regular. The result

is the theoretic curve. The greater number of divisions the more perfect the curve will be; but ten is generally sufficient for ordinary purposes. Should difficulty occur in ascertaining a distance which will enter into both divisions without a remainder, divide the steam line from clearance to the point of cut-off into equal spaces, then continue with these spaces through the remaining division, even should they project beyond the diagram, as the terminal pressure can be measured where the curve crosses the line designating the termination of the diagram.

To Compute the Average Pressures.

Divide the diagram into a number of equal spaces by lines drawn at right angles to the atmospheric line; ten is usually sufficient, but twenty is better if great accuracy is required. A proportional divider, with a small try-square, answers every purpose.

In non-condensing engines, when calculating the average pressure on the steam side of the piston for the whole stroke, the mean pressure in each division or space enclosed by these lines, between the upper line (steam and expansion) and the atmospheric line, should be first ascertained. This may be done either by carefully measuring each space between the atmospheric line and the upper line of the diagram by *the scale* corresponding to the spring used in the instrument, and the sum of these measurements divided by the number of spaces gives the average pressure per square inch upon the working side of the piston,

or average impelling pressure for the whole stroke; or upon measuring the spaces with a *common rule*, divide their sum by the number of spaces, and multiply the quotient by the number of the spring, and the result is the same. Proceed in like manner to find the average resisting pressure upon the opposite side of the piston, measuring the distance in each space between the lower line (counter-pressure and compression) and the atmospheric line; the *difference* between the average impelling pressure and the average resisting pressure gives the mean *effective* pressure exerted. Should the expansion line fall below the atmospheric line, the area of the loop (see Fig. 91) thus formed should be measured in like manner and deducted the same as the compression and counter-pressure. If the diagram is also divided by lines drawn parallel to the atmospheric line into equal spaces and corresponding to a certain number of pounds pressure, say five pounds, as per scale, beginning at vacuum, the operator is enabled readily to read the general characteristics by sight. A very simple method of measuring diagrams has been suggested which is much easier than either of the above and reduces liability of error. Take a narrow strip of paper which has a straight edge, place it across the diagram, and let one end of this strip come directly over the atmospheric line; then with a knife blade or sharp pencil mark the length of the first space as determined by the steam line; then move the paper along to the next space, placing the mark made by

the pencil over the atmospheric line; then make another mark at the point where it crosses the steam or expansion line, whichever it may be, being careful always to take a point on the upper line, which shall represent the mean length as nearly as possible; so proceed until the length of each space has been added to the first; then measure with a rule from the end of the paper to the last pencil mark, divide this by the number of spaces to get the average length, and multiply the quotient by the number of the spring in use, and the result is the average impelling pressure per square inch. Proceed in like manner to measure the average resisting pressure, etc. Ten is the usual number of spaces used, but for exactness twenty is better.

A quicker method of ascertaining the *effective pressure*, whether in condensing or non-condensing engines, is to measure the spaces between the upper and lower lines of the diagram without regard to the atmospheric line, and then proceed in the manner as before stated. This does away with separate measurements, excepting when a loop is formed in non-condensing engines.

CHAPTER X.

SLIDE VALVES.

THIS is a branch of the subject deserving the special attention of the engineer. Its importance in regard to the economical working of the steam engine cannot be overestimated.

The slide valve ordinarily used in high pressure engines and the manner of its operation is well known to nearly every practical mechanic and engineer. It will be remembered that the operations of admitting the fresh steam and releasing the waste steam are alternately performed by the same valve and the same motion. The valve being made to slide backwards and forwards upon the face of the ports, opens and closes the several passages in their turn. The two extreme ones called the steam ports, communicate with each end of the cylinder. The middle one is called the exhaust port, and its corresponding passage terminates in a pipe open to the atmosphere. Steam is admitted freely into the steam chest from the boiler, and the valve is made of sufficient length to cover all the ports, when it is placed in the centre of the stroke. When it is in this position no steam can enter the cylinder, but as the valve moves

on one of the ports opens, the arrangement of the valve gearing being such, that when the piston is ready to begin its stroke, the steam port begins to open. During the stroke of the piston, the valve not only travels to the end of its stroke, but also returns to the point from whence it set out, and its continued motion in the same direction finally closes the valve and prevents any further admission of steam. The steam has now done its work and must be removed. In the middle of the valve a hollow chamber is formed, of sufficient length to open between the ports.

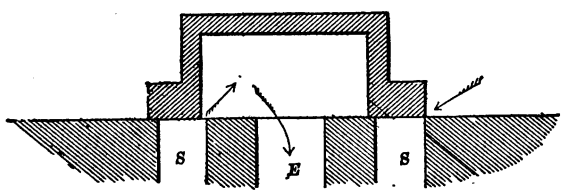


Fig. 96.

As soon as the edge of this chamber passes the edge of the steam port, the pent up steam finds vent and rushes through the exhaust port and escapes through the exhaust pipe into the atmosphere. Now looking at Fig. 96 you will notice that the exhaust port opens when the steam port closes, and that both happen just at the end of the stroke. The perfection of a steam valve, other things being equal, consists in the degree of nicety with which its motion is timed relatively to the motion of the piston. The functions of the piston are absolutely dependent upon the proper

timing of the admission and release of the steam. A most slight and apparently trifling error in the adjustment produces a most serious effect upon the consumption of fuel. If from any cause the valve should open to admit steam for a fresh stroke before the preceding stroke is finished, it opens too soon, and an unnecessary resistance to the piston is produced. If on the other hand, the valve should delay its opening until the piston had begun its return, it opens too late, because then the steam has to fill uselessly the space left vacant, and hence a waste of steam and loss of power. As far then as the admission of steam is concerned, it is a necessary condition that the *steam* ports should open neither before nor after, but at the precise moment when the stroke commences. Some engineers recommend giving the valve "lead" as it is termed, that is to say, setting it so as to open a little before the end of the stroke, but it is an open question whether the slightest advantage is gained by so doing to a greater extent than is necessary to compensate for any slackness or lost motion in the valve gearing or for their expansion when heated by the steam, and $\frac{1}{16}$ of an inch is quite sufficient in a well-constructed engine. It is also an open question whether it would not be better to bring the piston to a state of rest by the "compression" of the exhaust steam than by means of any lead to the steam valve at all. Now the valve shown in Fig. 96 ratifies the conditions for the *admission* of the steam; it opens exactly at the right time; the steam begins to enter

as the piston begins to move as it follows it steadily and effectively throughout the stroke. Whatever *time* the piston takes for its journey, the steam is allowed as much time to follow it. At first the opening is small, but then the motion of the piston comparatively slow and therefore the supply keeps pace with the demand.

As respects the *release* of the steam when the stroke has been completed the performance of this valve is altogether unsatisfactory, and here lurks the cause of the difference in the performance of the old and later engines.

But it may be said that the release does appear to take place at the right time, because it occurs just when the piston has finished its stroke, and if it were to occur before, a loss of power would ensue. This is a very plausible view of the case, and the one which delayed for years the saving of fuel which has since been effected. Sufficient attention was not bestowed upon what was going on in the cylinder or upon the facts which might have indicated them; to fill and empty a cylinder full of steam are operations requiring *time.* The time required for filling the cylinder with steam necessarily corresponds with the duration of the stroke, whatever its duration may be. But this cannot be the case as regards the second operation—the emptying of the cylinder. This ought to be performed in an *instant,* or otherwise the steam continues pent up when it ought to be liberated, when it ought to assume its minimum pressure—the pres-

sure of the atmosphere—and exerts an injurious counter-pressure against the piston, tending to increase the resistance to be overcome. To effect the free and rapid discharge it is necessary not merely to open the communication to the exhaust pipe, but to open a wide passage and to have this done by the time the piston commences the return stroke. The valve alluded to cannot accomplish this, its motion being gradual, not instantaneous, as it should be. The passage only begins to open when the piston is in its turn, and it is not wide open until the piston has travelled through one-tenth of its entire stroke. The steam in the cylinder is restrained from escaping, being, as it were, wire-drawn in the passage out, and consequently takes considerable time to assume the pressure of the atmosphere. In the meanwhile the new stroke has begun and been partly completed, and so far the piston has had to contend with a resistance altogether illegitimate, a resistance in many cases—especially at high speeds—nearly equal to all the other resistances put together. It was not until the year 1838 that the true cause of the trouble was suspected and a remedy applied. It had been thought, before that time, that giving an engine lead tended to improve its speed when already running at a high rate. This was attributed to the opening of the steam port being wide at the commencement of the stroke, thereby increasing the facility for the entrance of the steam in following up the piston. Its true explanation was found to be the *earlier release of the*

waste steam and consequent diminution of resistance. As sometimes three-eighths of an inch, or even one-half of an inch, "lead" was given in high-speed engines, it was decided to try the effect of opening the exhaust passage earlier by the same amount while the steam port should still be made to open only at the beginning of the stroke. An engine was chosen for the experiment the valve of which resembled Fig. 96, placing the valve on the ports so as to allow the exhaust passage to be three-eighths of an inch open, the steam port at the same time to be one-quarter of an inch open. This space, therefore, was closed by adding to the length of the valve at each end one-quarter of an inch. The eccentric was, of course, shifted on the shaft to correspond with the alteration, and the engine with the altered valve (see Fig. 97) again set to work. It is almost needless to say the saving of fuel was very great. The amount by which the valve at each end overlaps the steam ports (see Fig. 97) when placed exactly over them is technically termed the

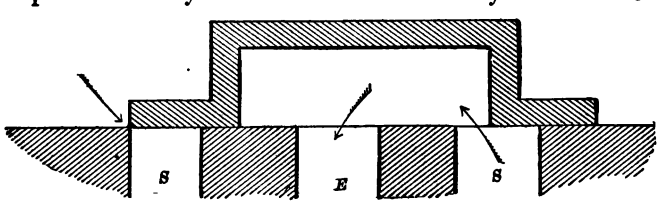


Fig. 97.

"lap." The lap of the valve being three-eighths of an inch, the exhaust passage was about three-eighths of an inch open when the stroke was finished.

Lap.

The importance of putting lap upon a slide valve will be better understood by noting what would happen without it. If there were no lap the opening for steam would be represented by O D (see Fig. 98), and the result would be that the steam port could only be perfectly closed at the precise instant when the valve was in the middle of its stroke and moving most rapidly. From what has been been said it is apparent that a valve of this kind (one without lap) is unsuitable for an engine, the better plan being that the steam should be compressed or cushioned on one side of the piston, so as to assist in bringing it to a state of rest, and that the driving pressure on the opposite side should be relieved by opening a passage to the exhaust or releasing the steam just before the stroke terminates. This prevents the violent jerk and strain which would come upon the crank-pin if the steam were thrown with full force upon the piston when the crank is on the centre.

The value of an indicator diagram in interpreting the action of a slide valve can now be made clear. Referring to Fig. 98, it will be noticed that the moving parts are attached to a board carrying a sheet of paper on which the circles describing the centres of the crank-pin and centre of eccentric are recorded; and below this is a space for tracing the indicator diagram. The crank and connecting rod which actuate the piston are at the back of the board, but an index arm, O H, is placed in front and moves with the

crank, thereby transferring its apparent motion to the part where it can be seen. The eccentric is represented by an actual crank, O P, whose extreme end describes the smaller circle, and the rod P L carries on the motion of the valve. The point P can be shifted along the arm O T, thereby varying the amount of travel of the slide, and the length of the rod P L can also be adjusted. In this way the effect produced by any deviation from the proper length of the eccentric rod can be studied. We are now prepared to trace out the diagram as given by an indicator. The crank being horizontal with the piston at the end of its stroke, the first thing to be done is to place the valve in the correct position for admitting steam by setting back O P until the lap is allowed for. The valve then opens, and if the pressure of the steam is sufficiently maintained the indicator pencil will trace the steam line A B. When the crank gets to the end of first dotted line, A is closed, expansion begins, the pressure falls, and we have the expansion line B C. At the point marked "release" the valve is moved so far to the left as to open a passage from A to C, and the release of the steam (exhaust) begins. The pressure falls from C to F, and continues very low till the point marked "compression" is reached, when B closes and the steam in the corresponding end of the cylinder is "cushioned" so as to increase its pressure, the pencil rising from M to A when the double stroke has been completed. The object and effect of putting "lap" upon a valve are two-fold:

1st, to give a free release to the exhaust steam, and, 2d, to produce a fixed amount of expansion.

The "lead," of which mention has been made, is outside lead, that is, it relates to the *admission* of the steam; but, of course, "lead" can be given to the exhaust side of the valve, in which case it is called *inside* lead. The four principal points in the valve motion are: 1st, the admission of the steam; 2d, the cut-off; 3d, the release or exhaust, and, 4th, the compression or cushioning of the steam behind the piston.

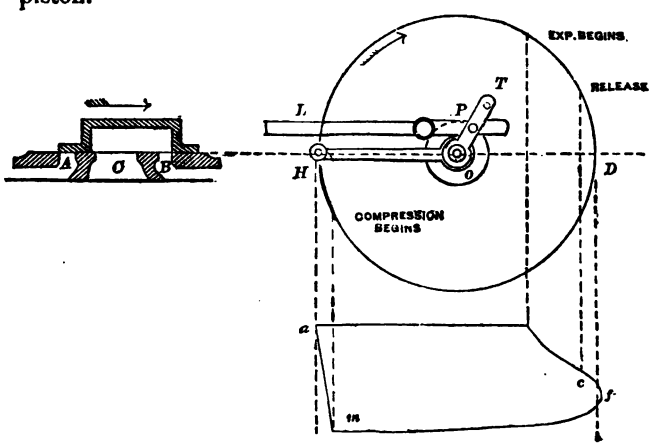


Fig. 98.

*How to Set a Slide Valve.**

It is first necessary to find the two centres for the cross-head. A, in Fig. 99, is the rim of the fly-wheel, and B, a piece of wood of a length to reach from the

* Frank C. Smith.

floor or foundation to about the height of the centre of the shaft. On the guides A, Fig. 100, draw a line *a*, at or a trifle beyond the travel point of the cross-head. Measure off a short distance (2, 3, 4 or 5 in.) on the guide from line *a*, and draw the line *b*. Place the cross-head as near on the centre as can be done with the eye, and turn the fly-wheel, the crank-pin travelling up till the cross-head arrives flush with line *b*, as shown, B being the cross-head. Then with

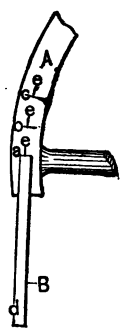


Fig. 99.

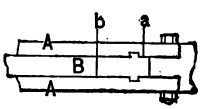


Fig. 100.

the stick resting on the floor or foundation, and against side of fly-wheel, make a mark *a*, Fig. 99, as shown. Now return the cross-head to the centre, revolving the fly-wheel in an opposite direction to that in which it was first moved, till the pin passes the centre and travels down, and the cross-head has again arrived at line *b*, as shown in Fig. 100. The stick B remaining in the same position, another line *c*, may now be drawn flush with the end of the stick,

The centre between *a* and *c* may now be found, and drawn as *b*. Now, when the line *b* is brought flush with the end of the stick by turning the wheel, the cross-head will be on the centre. A similar operation for the other centre will also ascertain it. The length of the eccentric rod is next in order, and should be lengthened or shortened as the case may be, till the valve opens one port about or nearly as far as the other. While doing this the position of the eccentric makes no difference, and may, in fact, be fastened anywhere. Having approximated the

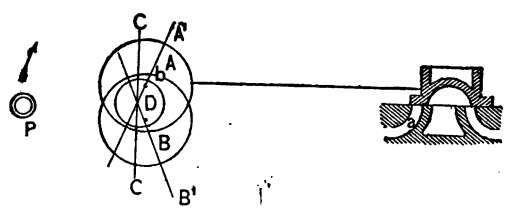


Fig. 101.

correct length of the rod, place the engine on the centre (either). The direction in which the engine is intended to run being known, the position of the eccentric must be ascertained. If the engine has a rocker-shaft, the full part or belly of the eccentric will follow the crank-pin; if there is no rocker-shaft, the full part of the eccentric will lead the crank-pin, being in either case nearly at right angles with the pin. The engine being on the centre, as in Fig. 101, and, having no rocker-shaft, we will suppose it is to run in the direction of the arrow. As the eccentric in

this case leads the pin, it will be in the position of A. Now adjust it till the required lead appears at *a*, fasten it, and try the lead when the engine is on the other centre. Whatever difference there is in the lead, lengthen or shorten the rod till the lead is equally divided on both ends, not moving the eccentric till this is accomplished, and when it is, shift the eccentric to the crank if there is too much lead, and from it, if there is not enough.

The centre of the eccentric, *b*, will then be the lap and lead from the centre line, *c c*. If the engine was

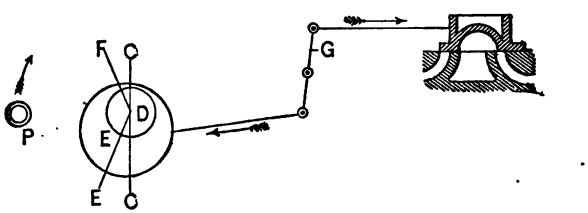


Fig. 102.

to run in the opposite direction, the eccentric would occupy the position of B. That the position A is the correct one, is evident from inspection, for imagining the pin *p* to commence and travel in the direction of the arrow, it is evident that the eccentric A will drive the valve from left to right, opening the port *a* as required. If we connect the valve-stem to eccentric B, and suppose the pin to still travel in the direction of the arrow, the eccentric would drive the valve from right to left, and close the port *a*, and it is plain that B is not in the correct position for the

direction of the arrow. However, if the engine is to travel in the opposite direction, it at once becomes evident that B is in the correct position for that direction. In either case, the valve occupies the same position when the pin *p* is on the centre. Locomotive engineers find in this fact an explanation for setting a slipped eccentric, by throwing the reverse lever in the opposite direction to the slipped eccentric, marking the valve-stem, throwing the lever in the motion for the slipped eccentric, and shifting the eccentric till the mark on the valve-stem reappears in the same relative position as when it was made, as the valve occupies the same position when the engine is on the centre, whether the engine runs forward or backward. By examining Fig. 102, it will be seen that the rocker-shaft makes all the difference in the world, in fact, the eccentric stands opposite to what it would without the rocker-shaft. When the engine runs in the direction of the arrow, the eccentric pulls the eccentric-rod in the direction of the arrow under it, and drives the valve-stem in the direction of its arrow, from left to right, as is required. The rocker-shaft just reverses the order of things, that is, it causes the eccentric to be the lap and lead *nearer* to the pin from a centre line *c c*, and also *follow* the pin, while without the rocker-shaft, the eccentric is as seen in Fig. 101, the lap and lead further from the pin from the line *c c*, and it also *leads* the pin. When the rocker-shaft is used, it should stand at right-angles with the valve stem, when the valve is over the centre of the seat.

CHAPTER XI.

THE PISTON AND ITS RINGS.

WE come now to the piston and the method used for packing it so as to prevent any steam from passing from one side to the other.

The piston shown in Fig. 103 is the one in general use, and which has been the standard for many years

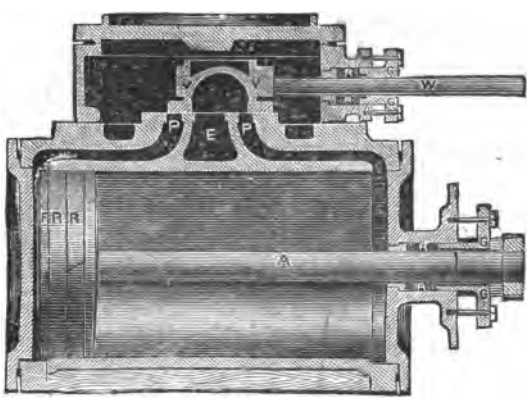


Fig. 103.

notwithstanding its many well-known defects. Its construction is about as follows: It is made of cast iron and is cast in two pieces. The main body to which the piston-rod is attached is called the piston

head, and the other part (marked F), which is used to keep the rings in place, is called the follower, and is attached to the piston by means of bolts called follower-bolts. These follower-bolts are generally made of composition, but steel ones are stronger and better and not so liable to be twisted off. The piston is made to work steam-tight in the cylinder by means of two packing rings (marked R R) made of cast iron or brass, generally the former. These rings are turned a little larger than the diameter of the cylinder and then cut diagonally (as shown in the figure) so that they can be set out or expanded to fill the cylinder completely by means of steel springs set out by bolts. The place where one ring is cut is placed opposite to that of the other so as to break the joint, which is done to prevent the steam passing through one joint from passing through the other. There is another ring made of cast iron, and as wide as both the others, placed on the inside, which furnishes a bearing for the springs and causes them to press equally against the outer rings. The inner ring is cut also.

This piston is now being rapidly superseded by an improved piston (as shown in Fig. 104), which shows the piston wrought in one solid piece, and dished out so as to form a deep surface of contact with the sides of the cylinder. Here the depth of the guiding surface of the piston is four inches, and the three grooves shown in section are intended for the reception of metallic packing rings, as applied by Mr. Ramsbottom

about 1854, and which form the simplest method that has been devised for keeping the piston steam-tight under the high pressure employed in locomotive engines. The contrivance is thus described in a paper on an improved piston for steam-engines: "Three separate grooves, each $\frac{1}{4}$ inch wide, $\frac{1}{4}$ inch apart, and $\frac{1}{16}$ inch deep, are turned in the circumference of the piston, and these grooves are fitted with elastic packing rings. These rings, which may be of brass, steel, or iron, are drawn of a suitable section to fit the

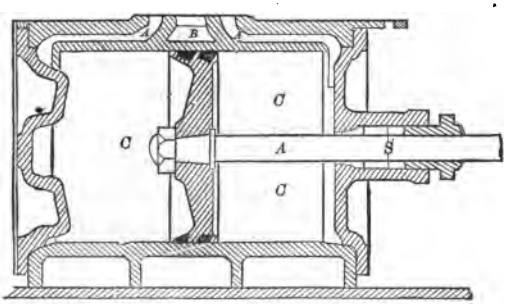


Fig. 104.

grooves in the piston, and are bent in rollers to the proper curvature, the diameter of the circle to which they are bent being about one-tenth larger than the cylinder. They are placed in the grooves in a compressed state, and along with the body of the piston are thus put into the cylinder, care being taken to block the steam-port. The rings are therefore forced outwards by their own elasticity, which is found quite sufficient to keep them steam-tight." Of

course the rings are put on so as to break joint. One object in the construction of this particular piston has been to reduce as much as possible the amount of rubbing surface. It is a maxim in books on mechanics that the amount of friction is independent of the extent of surfaces in contact; but that rule only applies where the surface is directly supporting a pressure, and it has nothing to do with the friction of a piston, where an increase of surface undoubtedly increases the friction. Here the lightness of the piston reduces the friction, and so also does the small amount of elastic surface pressed against the interior of the cylinder.

As to the amount of bearing surface, it appears that for an 18-inch piston it would come to about 42 square inches, whereas in a piston of the same diameter with 2½-inch packing rings the area of rubbing surface would be 141 square inches. The simplicity of construction is also an advantage, the only workmanship expended on the piston being that of turning its rim and forming its centre. The packing rings are drawn as ordinary wire, and are afterwards bent into shape, the cost of production being very small.

The mode of attaching the piston-rod is apparent from the sketch. There is a shoulder, and the rod terminates in a coned end, the whole being screwed up tight by a nut. The cylinder covers are copies of the configuration of the piston, thereby avoiding a waste of steam.

CHAPTER XII.

SAFETY VALVES—THEIR ANTECEDENTS, INVENTION, HISTORY, AND CALCULATION.*

THE frequency of requests for an explanation of the method of calculating the proportions of the levers and weights of safety valves, shows that the problem, simple though it is, is yet not properly understood by many of our mechanics and engineers.

For the benefit of the younger portion of our readers, as well as for some of the older, we have undertaken to give the antecedents of the safety valve, its invention, and a review of its history, and also to explain the manner of calculating and proportioning it in all its parts. We do not pretend to offer much that is new or original, but have tried to give that which will be the most useful, and in as simple language as is consistent with the subject matter.

Mathematics cannot be wholly dispensed with in an explanation of this kind, but in each case, where possible, written rules, together with the particulars of working examples, are given, so that the reader may study the subject for himself.

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* W. Barnet Le Van.

Steam.

Steam has been noticed ever since the first heating of water and boiling of food for domestic purposes. The daily occurrence implied by the expression, "the pot boils over," was as common in antediluvian as modern times; and hot water thus raised was one of the earliest observed facts connected with the expansion of vapor. From allusions in the most ancient writings we may gather that the phenomena exhibited by steam were closely observed of old. Thus Job, in describing Leviathan, alludes to the puffs of volumes that issue from under the covers of boiling vessels: "By his neesings a light doth shine," and "Out of his nostrils goeth smoke (steam) as out of a seething pot or cauldron." In the early use of the vessels last named, and before experience had rendered the management of them easy and safe, females would naturally endeavor to prevent the savory contents of their pots from flying off in vapor, hence attempts to confine it by covers; and when these did not sufficiently close, a cloth or some similar substance interposed between it and a stone or other weight placed upon the top *to keep all tight*, would also be very natural. Then as the fluid began again to escape, further efforts would be made to retain it by additional weights. In this manner, doubtless, many a contest was kept up between a pot and its owner, till one gained the victory; and we need not the testimony of historians to determine which this was. In those times it was not generally known that a boiling cauldron contained a

spirit impatient of control, that the vessel was the generator of an irresistible power, and the *cover a safety valve;* and that the preservation of the con-

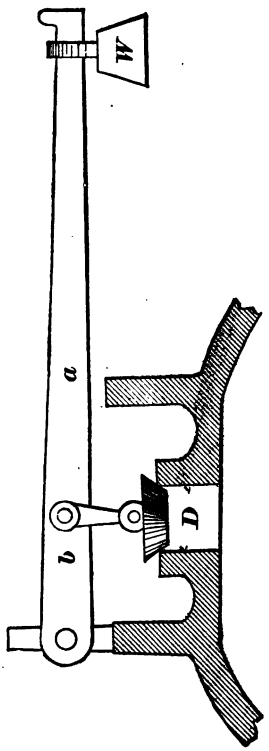

Fig. 105.—Papin's Safety Valve, A. D. 1695.

tents, and the security of the operator, depended upon letting the cover alone, or not overloading it; hence it no doubt often happened that the confined vapor threw out the contents with violence, and then it was

that primitive cooks began to perceive that there was death as well as life in a boiling pot. In this manner we suppose females were the first experimenters on steam, and the earliest witnesses of steam boiler explosions.—["Ewbank's Hydraulics," 391.]

Valves.

The bellows was probably the first instrument of which they formed a part. No other machine equally ancient can be pointed out in which they were required.

That the bellows is of antediluvian origin there can be little doubt, for neither Tubal-Cain nor any of his pupils could have reduced and wrought *iron* without it.

Strabo attributed the bellows to Anacharsis, who lived about 600 years B. C. Pliny (B. vii., 56) attributes it with greater propriety to the Cyclops, who are supposed to have flourished before the deluge. The prophet Jeremiah, who lived long before Anacharsis, speaks of it in connection with metallurgical operations. "The bellows are burned, the lead is consumed of the fire; the founder melteth in vain." Isaiah, who lived still earlier, namely, in the eighth century B. C., alludes to the blacksmith's bellows: "The smith that bloweth the coals in the fire." Job, nine or ten centuries before the Scythian philosopher flourished, speaks of the blast-furnace as common: "They gather silver, and brass, and iron, and lead, and tin, into the midst of the furnace, to *blow the fire* upon it

to melt it" (xxii. chapter, 20th verse). Homer, as might be supposed, could not fully describe the labor of Vulcan without referring to this instrument. His account of the great mechanical work is equally descriptive of a smith and his forge of the present day:

> Obscure in smoke, his forges flaming round,
> While bathed in sweat from fire to fire he flew;
> And puffing loud, the roaring bellows blew,
> * * * * * * * * * *
> Just as the gods direct, now loud, now low,
> They raise a tempest, or they gently blow.
> —*Iliad*, xviii., 435, 545. *Pope.*

But by far the most important improvement on the primitive bellows or bag, was the admission of air by a *separate* opening—a contrivance that led to the invention of the *valve*, one of the most essential elements of steam, of water, as well as pneumatic machinery. The first approach to the ordinary valve was a device that is still common in the bellows of some African tribes. A bag formed of the skin of a goat has a reed attached to it to convey the blast to the fire, and the part which covered the neck of the animal is left open for the admission of air. This part is *gathered up* in the hand when the bag is compressed, and opened when it is distended. ["Ewbank's Hydraulics," 235.]

The spindle valve, or such as have *long* shanks to prevent their rising too high, and to guide them when descending, is said to be of French origin.

A safety valve is an appendage to a steam boiler

for the purpose of limiting the pressure of steam to that consistent with the normal safety strength of the boiler; it is, in fact, the weakest point of a boiler, for everything else resisting the steam pressure must be stronger than the *safety valve*—and its name indicates its office. Therefore, the physical laws involved in the operation of a safety valve deserve a careful study, because it is not only a safety for the steam boiler, but a safety for human life and property, depending upon, the proper construction of the safety valve.

A safety valve should be large enough to allow all the steam that may be generated in the boiler to escape with sufficient rapidity to prevent initial blowing-off pressure being exceeded by more than five per cent.

It is supposed that the gradual increase of pressure can never take place if the safety valve is in good working order, and if we have proper proportions. It should, however, be stated that engineers and firemen do not, in practice, place their trust in the safety valve alone, and that to their watchfulness and attention the public are more indebted for safety than to the apparatus which is designed to regulate the pressure.

It is, however, an indispensable addition to a steam boiler, and should be made, if possible, so that under its automatic action no considerable increase of pressure will be possible from ordinary evaporation.

Every safety valve should be so located that it can be opened by hand at least twice each day; or, if not convenient to so place it, a cord should be secured to the lever or stem of the valve so as to operate it as

above to keep the valve free and in good working order.

A safety valve should allow no pressure to accumulate beyond the point at which it may adjusted, nor should it discharge an excessive quantity before closing. Ever since the days of the illustrious Doctor Papin (Fig. 105) the common type of valve has existed, with its peculiar and numerous disadvantages. Its supreme fault is its limited action, and its lift decreases with adjustment for high pressures, making its operation especially restricted. So slight is the lift of an ordinary valve that, with a diameter of six inches, it gives an opening of less than one square inch of area. In consequence of this imperfection increased diameters are introduced, involving large friction surfaces with their accompanying corrosion. Prominent among the various enemies to perfection there is the danger attending the exposure of a safety valve of the common form, with its extended lever stretched forth to receive any treatment which the careless may wish to employ.

Some Facts for the Consideration of Boiler Makers and Boiler Owners.

One of the prime causes of boiler explosions is the gradual and insidious increase of the pressure of steam beyond the endurance of the boiler; but to every boiler there is a limit of pressure within which it is substantially safe. This point should be ascertained by hydraulic test annually, and no excess of pressure

beyond this limit should be allowed at any time. The only *sure preventive* is a safety valve which is all its name implies. The diameter of a safety valve is not a test of its efficiency. A valve is effective in direct proportion to its lift, other conditions being equal. The higher the pressure of steam, the less will a common safety valve lift; at most its lift is very slight, and with the increasing pressure of steam the lift will not increase sufficiently to relieve the boiler under all circumstances; but the *pressure* can and may increase until an explosion occurs, while the valve is in operation. The common safety valve has much to answer for. Owing to the great friction of its parts, it will not open until the *pressure is above* what it is set at; it will continue to blow *after* the pressure of the steam has fallen far below the point of opening; it *wastes* large quantities of valuable steam in operation. There are other grave faults, but these stated are sufficient to condemn it. Instead of standing guard over the boiler, a sentry has to be set over it, and should he by accident, ignorance or negligence, not properly attend to his duties, the boiler is without any safeguard whatever. Hence the importance of any device which shall reduce the danger to its minimum. A safety valve which is automatic, certain in its action, prompt in opening and closing at the required points of pressure, and can be fully relied upon to relieve the boiler under all circumstances, is what is necessary.

"Necessity being the mother of invention," the

necessity for a real safety-valve has resulted in the

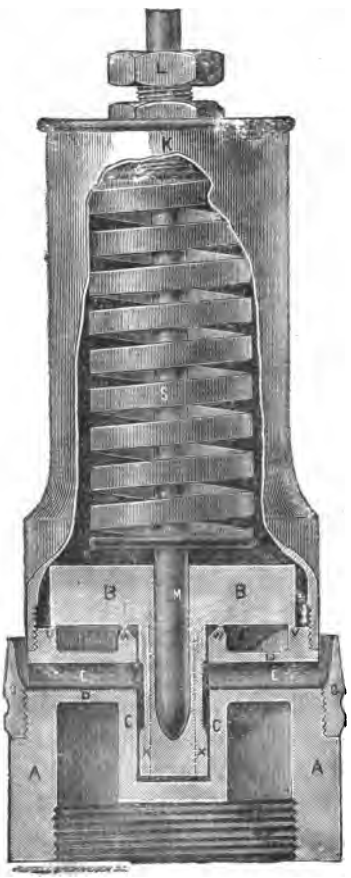

Fig. 106.

invention of several improved valves by American

engineers, the most popular, efficient and reliable makes of which we will now illustrate and describe.

Crosby Adjustable Pop Safety Valve.

Fig. 106 represents the valve as designed by Geo. H. Crosby, of Boston, Mass. These valves are tested under steam pressure and set to open at the exact point of pressure desired, and are adjusted to close at about two pounds reduction ordinarily; both of these points can be readily changed by the operator without removing it from the boiler or reducing steam. It is believed any person of ordinary intelligence will readily understand the principle and operation of this valve by the following description and explanation.

The valve proper B B rests upon two flat annular seats V V and W W on the same plane, and is held down against the pressure of steam by the steel spiral spring S. The tension of this spring is caused by screwing down the threaded bolt L at the top of the cylinder K. The area contained between the seats W and V is what the steam pressure acts upon, ordinarily, to overcome the resistance of the spring. The area contained within the smaller seat W W is not acted upon at all until the valve opens.

The large seat V V is formed on the upper edge of the shell or body of the valve A A. The smaller seat W W is formed on the upper edge of a cylindrical chamber or well C C, which is situated in the centre of the shell or body of the valve, and is held in its place by four arms D D radiating horizontally

at right angles to each other, and connecting it with the body or shell of the valve. These arms are hollow, and form four passages E E for the escape of the steam or other fluid from the well into the air when the valve is open. This well is deepened so as to allow the wings X X of the valve proper to project down into it far enough to act as guides. The area of the apertures, at the outer ends of the passages through the arms, is reduced more or less at will, by screwing up or down the adjustable ring G G.

Action of the Valve when Working under Steam.

When the pressure under the valve is within about one pound of the maximum pressure required, the valve will open slightly, and the steam will escape under the larger seat into the cylinder surrounding the spring, thence into the air; the steam is also forced under the smaller seat into the well, and thence through the passages in the arms into the air. As soon as the pressure attains the exact maximum point, the valve will be lifted so high as to force the steam into the well faster than it can escape through the apertures in the arms; a pressure will then accumulate under the inner seat, which will be in excess of what was required to overcome the increasing resistance offered by the spring, and acting upon the additional area presented, at once forces the valve wide open and rapidly relieves the boiler. This pressure under the inner seat is of itself differential. The valve then at once slowly settles down and the

pressure under the inner seat as slowly diminishes,

Fig. 107.--Crosby Adjustable Pop Safety-Valve, for Portable Engines.

and so continues until the area of the opening, under

the smaller or inner seat, is less than the area of the apertures in the arms for the escape of the steam; the pressure then ceases and the valve promptly closes. The point of opening can be readily changed while under steam by screwing the threaded bolt at the top of the cylinder, either up or down; and the point of closing is as easily adjusted, by screwing up or down the ring surrounding the outside shell or body of the valve. The seats of this valve are flat and do not wear out and leak so readily as bevelled seats.

Directions for Grinding and Adjusting.

GRINDING.—This valve having flat seats on the same plane is very easily ground by following these directions, viz.: Do not grind the valve to its seats on the shell by grinding them together, but grind each part separately, *i. e.*, grind the valve proper on a perfectly flat surface of iron or steel, until its two bearings are exactly on a plane and with good smooth surfaces; then take the shell and grind its seats in precisely the same manner; rinse both parts in water and put together, and the valve will be found to be tight; to ascertain when the bearings are on the same plane use a good steel straight edge.

ADJUSTING.—First screw the ring down as far as it will go; then screw down the nut which compresses the spring, until the valve opens slightly at the pressure desired, as indicated by the steam gauge; then screw up the ring slowly until the valve pops. If the loss by relief is too great, screw the ring down

slightly until the loss is the exact number of pounds desired, and then fasten by the set screw.

Fig. 108.—New Style, Crosby Lock-Up Pop Safety Valve for Stationary Boilers.

CAUTION.—Care should be taken that no red lead, chips, or any hard substance be left in the pipes or

couplings when connecting the valve with the boiler. Never make a direct connection by screwing a taper thread into the valve, but make the joint with the valve by the shoulder.

The Scovell Pop Safety Valve.

The Scovell "Pop" Safety-Valve, for locomotive, stationary, portable and marine boilers (see Fig. 109), has recently been brought out by the Hancock Inspirator Co., Boston, Mass.

The passage D forms the steamway between the valves B and C. The passage F conveys steam from the boiler to the valve B. The passage G conveys steam from the boiler to the valve A.

A set screw is used for the purpose of regulating the lift of the main valve A.

The cap surrounding the spring spindle M regulates the tension of the coil spring.

A lever is provided for the purpose of opening the valves by hand. The openings J K are for the purpose of allowing steam to escape into the atmosphere from the valves.

In operation, the valve B, it will be understood, simply operates the valve C. The valve B relieves the boiler. The valve B and lower disc of valve C are fitted so loosely in their cases, that steam freely passes around and above them, forming a steam counter-presssure or load above the valve B. When the valves are at rest their chambers are filled with steam at boiler pressure, and *at all times* the boiler

pressure acts upon the lower disc of valve C and the annular space surrounding the seat of valve B, but not so above them, as will be observed from the following description. The above description refers to the valve at rest. Its action in "blowing off" is as follows: As soon as the boiler pressure becomes greater than the resistance of the coil spring, the valve C is forced upwards from off its seat. As this occurs, the steam pressure above the valve B and lower disc of valve C begins to escape into the atmosphere, through the seat of valve C and openings J K. The boiler pressure continues to increase slightly until the valve C has opened sufficiently to allow the steam load above the valve B to escape through a passage and through the seat of valve C, and into the atmosphere more rapidly than it can get on top of and around the loosely fitted valves. The valve B then opens to its full height, and relieves the boiler of its excessive pressure, when the coil spring again forces the valve C back to its seat, causing the pressure to again accumulate in the chamber above the valve B, and force it back to its seat on top.

A trip lever is so arranged that a downward pressure causes it to lift the spring, and causes the valves to "blow off," but an upward movement of the lever will not exert any force on the valve to hold it down. The pressure can be easily changed at any time, by altering the tension of the coil spring with the cap screw.

It is claimed for the Scovell "Pop" Safety Valve,

that its relieving capacity is not restricted, and that

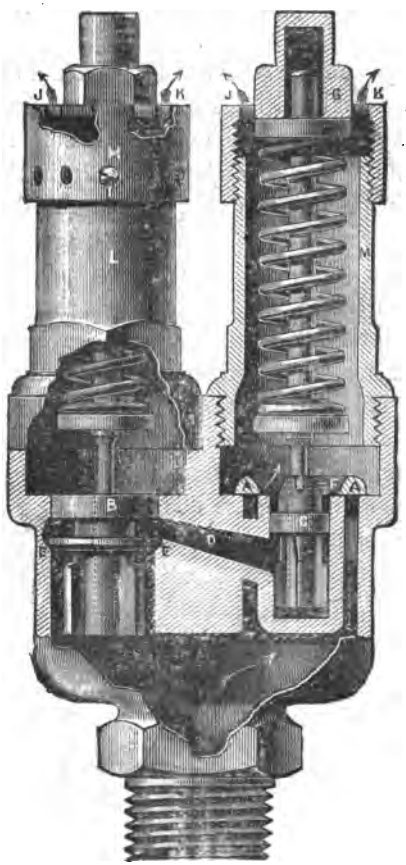

Fig. 109.

it lifts to its full height with all pressures, presenting an opening equal to the area of its discharge pipe.

Its seats are of the simplest form, and its precision of action is not subject to derangement by the wearing of its valves or their seats. No especial adjustment is necessary, and the seats can be reground or renewed without especial skill. Its friction surfaces are reduced to a minimum. The spring is not subjected to violent and sudden compression. It is thoroughly self-contained, and is exempt from the dangers of being tampered with. It opens with promptness and closes with a slight loss of pressure.

It is constructed of the best steam metal, which affords the greatest immunity from corrosion. These pop valves are manufactured with or without flanges and of various modifications, to meet all conditions. The outlets are also made suitable for locomotive and portable boilers, where no escape pipe is required. The manufacturers are the Hancock Inspirator Co., 34 Beach St., Boston, Mass.

CHAPTER XIII.

STEAM GAUGES.

Bourdon Pressure Gauge.

ABOUT the year 1849 Eugene Bourdon, of France, discovered that the free end or ends of a flattened tube, with enough elasticity for use as a spring, would move when pressure was applied through the medium

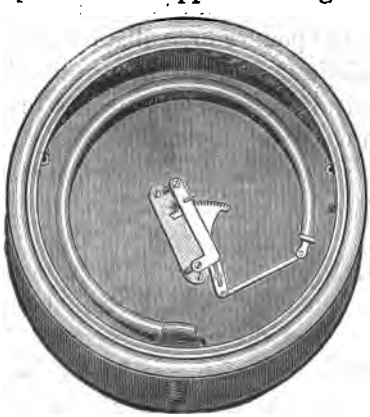

Fig. 110.

of a fluid, externally or internally; that the motion was in direct proportion to the pressure applied, and when the pressure was removed it would assume its former position. He at once conceived the idea of a

new pressure gauge, in which this should be the main spring or means of motion, and as originally designed (see Fig. 110) far excels any other instrument for sensitiveness and accuracy, but is best adapted for measuring low steam pressure and vacuums, or wherever a very delicate instrument is required.

Crosby Improved Pressure Gauge.

Although it is conceded that the hollow spring gauge, as invented by Bourdon, excels in delicacy and sensitiveness, yet, owing to its peculiar construction, it is not altogether adapted for general use. It has been found that a spring held only at one end vibrates from a slight shock or sudden change of pressure, causing the pointer to oscillate on the dial, wearing out the delicate mechanism operating it, and rendering it difficult to ascertain the exact pressure to be indicated in use; and further, that the dip of such a spring causes it to retain a portion of the water condensed in it, rendering it liable, in cold weather, to burst or be strained by freezing. To overcome these defects several devices have been made use of from time to time, but they have invariably been subject to other grave defects, the more important being the setting or straightening of the springs employed, when acted upon by a pressure less than the maximum indicated upon the dial, so rendering the gauge inaccurate and worthless. To meet the need of those wanting a secure and reliable gauge, the Crosby Improved Bourdon Gauge was produced; the interior view

being seen in Fig. 111. It originated from observations made of the motions of the free ends of the

Fig. 111.

Fig. 112.

springs or tubes already in use, while under variable

pressures. It was found that not only the horizontal motion of the springs could be utilized, which then was only employed in the gauges in use, but also that of the upward or perpendicular action of the same spring, if of a given length; and that by uniting these motions by proper mechanism it all could be transmitted to the pointer. This permitted and required firmer or stiffer springs for measuring like quantities of pressure than any before used; experience has shown that under no circumstances of pressure employed, within the amount indicated upon the dial, can they be straightened or their original elasticity affected. This device also avoids and prevents any vibration of the pointer under action; and the springs being held at their lowest points, and having no dip, allow the water to return to the siphon, thus removing the danger of freezing by extreme cold. While this gauge partakes of all the good qualities of the original Bourdon, the defects are carefully eliminated, and the use of springs *one hundred per cent.* stronger than can be used in any other style of gauge is permitted, *so preventing its setting under any pressure that may be indicated upon its dial.*

CHAPTER XIV.

PRACTICAL NOTES ON THE MANAGEMENT OF STEAM ENGINES AND BOILERS.

Grate-Bars.

Question. What are the proper length and size of grate-bars?

Answer. When the furnace is more than four (4) feet long the bars should be put in in two lengths, but if it is four feet or less in length, one bar will suffice, in which case only two bearing bars will be required. When a center bearing bar is used for two lengths, it should be made like a double grate-bar, that is, with an opening or air-space in the middle. Grate-bars when hot expand considerably, and therefore they should not be put in tight, or too close together, but should have both end and side play, otherwise they will bend and twist out of shape and soon be destroyed.

Glass Gauges.

Q. What are glass gauges?

A. Glass gauges are simply thick glass tubes attached to the boiler for the purpose of showing the height of the water in the boiler, the same as gauge-cocks. They are more convenient than the gauge-

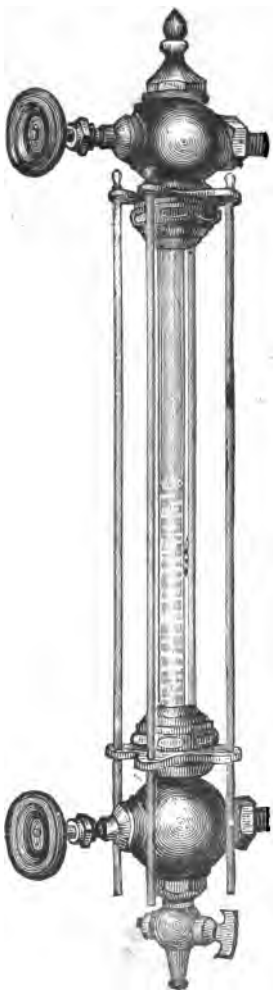

Fig. 113.

cocks, as the height of the water can be seen at a glance. As these gauges are liable to get stopped up by mud or other impurities in the water, they should be blown through occasionally to see that they are clear. The glass gauge should not be attached directly to the boiler, but to a pipe leading from the steam-chimney down to the solid water below, over, or near the crown-sheet. In this position it will not be affected by the foaming of the water. When putting in a new glass tube, should it be too long, you can cut it off as much as required by merely scratching it on the *inside* with a small round file. Any person who has never tried this method will be surprised how quickly and nicely it can be done. Little gum washers for packing the glass tube can be had at all dealers in engineer's stores, or they can be made out of sheet gum.

Some engineers pack them with lampwick, but I prefer the prepared gum washers. As glass gauges are very liable to break, a number of extra ones should always be kept on hand.

Gauge-Cocks.

Q. What are gauge-cocks, and what are they used for?

A. Gauge-cocks are small plug-cocks screwed into the boiler to show the height of the water. They are generally three in number, and placed one above the other, about 3 inches apart; the lower one should be fixed just above the level of the upper row of tubes, or back connection plate, and the water should *never* be allowed to get below it; if it does the tubes and connections will get overheated, and then should the feed-water be put on an explosion would be the result.

Low Water.

Q. But suppose, owing to the feed-pump not working, the boiler foaming, or any other cause, the water should fall below the lowest gauge-cock, what is to be done?

A. If the fires are light, and they can be hauled *quickly*, haul them; but should they be heavy, the better plan is to smother the fire with fresh coal, dust, or ashes out of the ash-pans; this will kill the fire for some time and render it harmless. Do not attempt to put the fire out by throwing water into the furnace, or the steam will rush out and scald you to

death. Do not raise the safety-valve, or open the stop-valve, or do anything that will lift the water up to the hot tubes or sheets; open the furnace door and connection doors, and let the boiler cool off; in an hour or so you can fill it up again with a hand pump. In some boilers, with contracted water and steam-room, the water will be lifted several inches above its true level, while the engine is in motion, and will fall as soon as the engine stops; thus, such a boiler might show six inches of water in the glass gauge, or gauge-cocks, while the engine was in motion, and yet drop entirely out of sight on stopping the engine; should this happen you should start the engine again, or raise the safety-valve to lift the water, and keep it lifted while you pump more in. The first thing to do in every case, when you stop the engine, is to see how the water stands in the boiler. Boilers addicted to foaming are dangerous, and need close watching.

Q. Do boiler-makers always place the glass water-gauge and gauge-cocks in their proper positions?

A. They should do so, but they often misplace them. When the top row of tubes and back connections are covered with water to the depth of three inches, the water should just be seen in the glass gauge and show in the lowest gauge-cock, and it will if it be properly set. I once had charge of a boiler which showed four inches of water in the glass, when the upper row of tubes was bare, and another which had eight inches of water over the tubes, when the water could just be seen in the glass gauge. Now, the

proper thing for every engineer to do on taking charge of an entirely new or strange boiler, is to fill the boiler (leaving the manhole open) so as to cover the top row of tubes or flues, and top of back connection, and then notice where it stands in the glass gauge and *mark* it; he can then always tell at a glance how the water stands in the boiler. No doubt a great many boiler explosions have resulted from this very cause of misplaced glass gauges, they showing plenty of water when the tubes were actually bare and red-hot.

How to Set a Safety-Valve.

Q. Will you inform me how to set a safety-valve?

A. As shown in the following figure:

Fig. 114.

Let—P = Power.	Short arm is the distance *A*—*B*.
W = Weight.	Long arm is the distance *A*—*C*.
S = Short arm.	Power is area of valve, multiplied by steam pressure.
L = Long arm.	Area of valve is found by multiplying the square of its diameter by the decimal .7854.
Then:	
P × S ÷ L = W.	
W × L ÷ S = P.	
S × P ÷ W = L.	
L × W ÷ P = S.	

Example.—Suppose in the above figure we have the following dimensions:

Diameter of valve 3 inches; pressure of steam 20 pounds per square inch; length of short arm (*a*—*b*)

3 inches; length of long arm (a—c) 30 inches. To find the required weight, we first find the power:

```
    3
    3
   ---
    9
  .7854
 -------
 7.0686  = Area of valve.
   20    = Pressure of steam.
 -------
141.3720 = Power.
```

Now, leaving out the fraction (.3720), we take the power, 141, which is near enough for practical purposes, and multiplying it by the short arm, 3, and dividing by the long arm, 30, we have $14\frac{1}{10}$ pounds as the proper weight of the ball to balance the pressure of 20 pounds per square inch. Thus:

```
   141
     3
30)423(14 1/10 =W.
   30
   ---
   123
   120
   ---
    3
  ---- = 1/10
   30
```

Proof.

$141 \times 3 = 423.$

$14\frac{1}{10} \times 30 = 423.$

In the above the weight of the valve, stem, and lever is not included. The weight of these can be easily found by using a spring balance, lifting them from the point B. Suppose in the above case, the valve, stem, and lever weigh 4 pounds. We deduct that amount (4 pounds) from the power (141), which leaves an unbalanced pressure of 137 pounds. Then, $137 \times 3 = 411$, which divided by $30 = 13\frac{7}{10}$, the weight of the ball. The engineer can set his safety-valve in

a practical manner by sliding the weight in or out on the lever, and *marking* it where the valve just begins to blow at different pressures.

Proper Lift of a Valve.

Q. What is the proper lift of a valve?

A. The proper lift of any round or conical valve, be it a safety-valve, check-valve, or poppet-valve, is $\frac{1}{4}$ of its diameter.

Thus a 4 inch valve has 1 inch lift.

2	"	"	$\frac{1}{2}$	"
1	"	"	$\frac{1}{4}$	"
5	"	"	$1\frac{1}{4}$	"
6	"	"	$1\frac{1}{2}$	"
8	"	"	2	"

Divide the diameter by 4, and the result will be the proper lift.

Repairs to Boilers.

Owing to imperfections in the iron, small cracks often appear in the crown-sheet, flues, and back connections. If in the crown-sheet, and not more than *two* inches in length, drill a hole, cutting the crack out, cut a taper thread and insert a wrought-iron gas plug (a number of which of different sizes should be carried for that purpose) smeared with white lead.

If in a flue, drill a number of small holes, and put in small rivets, hammering the heads out so as to cover the crack.

If the crack is more than two inches long, or if it

be a large hole which cannot be plugged, then you must put on a hard patch, and if the patch cannot be riveted on, then put it on with tap-bolts screwed into the sheet. Care must be taken to admit water to the patch, else the fire will soon destroy it.

Hard patches should be used on all parts reached by the fire, and soft patches on the other portions.

Q. What is the difference between a hard patch and a soft patch?

A. A hard patch is riveted on or put on with tap-bolts; a soft patch with bolts and nuts.

Q. What is the proper way to put on a soft patch?

A. You first make a pattern of the needed patch out of sheet-lead, then take a piece of boiler-plate, and forge a patch as near like the lead pattern as possible. Then drill as many 5-8 holes as are necessary, about 3 inches apart in the sheet, and corresponding ones in the patch. Next, mix some boiler-maker's cement, which is made of equal parts of white and red lead mixed with enough iron borings to make it a stiff putty; cover the inside of this patch with this putty, and it is ready to go on. Next, wrap some 5-8 bolts with lampwick smeared with white lead, pass the bolts through from the *inside*, and set the nuts up tight, placing a washer between all the nuts and patch.

Q. Suppose the patch is so situated that the bolts cannot be put through with the hand?

A. Then they must be "fished" through. Take a long piece of wire, pass it through the bolt-hole and out through the hand-hole, then tie the bolt to

the wire with a piece of strong string, giving about an inch slack, haul out the wire and the bolt will come out nicely in its place. This is called fishing a bolt, from its resemblance to hauling in a fish.

Leaky Tubes.

Q. What is the proper way to plug up a leaky tube?

A. Suppose the tube is 3 inches in diameter, and 7 feet long. You take two white-pine plugs 3 inches in diameter, tapering off to 2 7-8 inches, and about 4 inches long. Next, bore a 3-4 inch hole through the centre of the plug. Take a 5-8 inch bar, 7 feet 4 inches long, with a thread cut two inches in length on each end. Run the bar through the tube, put in the pine plugs, and drive them in flush with the tube. Place a saucer-shaped washer filled with red lead, putty, or boiler-maker's cement, on each plug, and screw up tight with nuts.

The following cut will show at a glance how this is done:

Fig. 115.

Q. Should not every boiler have two steam-gauges attached to it?

A. As nothing made by human hands is perfect, steam-gauges form no exception to the rule, and

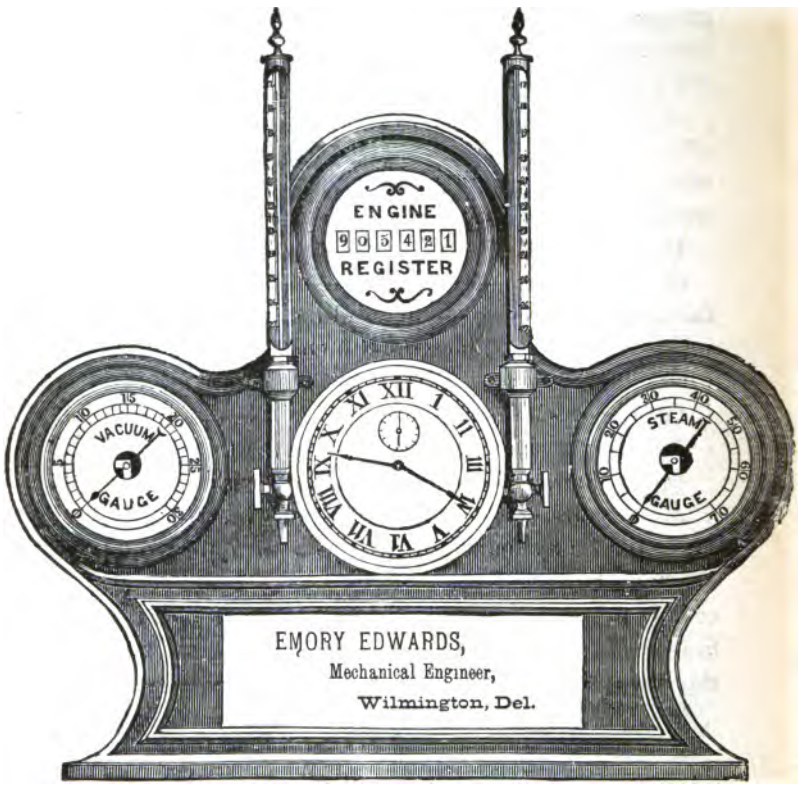

Fig. 116.

therefore there should be two, so that one may act as a check upon the other. But they should each be attached to the boiler by a separate pipe, because if they are both fixed to one pipe and that gets stopped up both gauges will be in error.

Q. Do not the pointers of steam and vacuum-

gauges vibrate violently sometimes, owing to the fluctuating pressure in the boiler or condenser while the engine is in motion?

A. When they do so, turn the cock on the gauge off until the pointer remains *almost* stationary, otherwise the springs which are very delicate will be weakened, making the gauge unreliable.

Q. Do not the pointers sometimes stick fast?

A. If they do, jar the gauge by slapping it with the hand so as to knock the pointers down.

Vacuum.

Q. What is a vacuum?

A. A vacuum means an empty space.

Q. How is a vacuum in a steam engine produced?

A. After the steam has done its work in the cylinder it is exhausted into the condenser, where it is condensed (turned into water again) by a shower of cold water; it then falls, in the shape of hot water, to the bottom of the condenser, and the *space* above the water in the condenser is a vacuum.

Q. Is the vacuum in the condenser a perfect one?

A. No; as more or less vapor always follows the condensation of the steam, and besides a small quantity of air enters with the condensing water. When a vacuum-gauge shows more than 28 inches of vacuum, the gauge is out of order and unreliable; as 28 inches (30 inches being perfect) is about all that it is possible to obtain in a steam engine, assertions to the contrary notwithstanding.

Back-Pressure.

Q. What is meant by back-pressure?

A. As it is impossible in practice to obtain a perfect vacuum in the steam engine there is always more or less vapor opposed to the motion of the piston, and this is what is called back-pressure; it is the difference between a perfect vacuum and that shown on the vacuum-gauge. Every two (2) inches of vacuum equal one (1) pound pressure.

How to Read the Counter, or Register.

Q. How do you ascertain the number of revolutions made per minute by the engine by the counter?

A. Note the figures on the counter at any time, and in one hour note them again; subtract the former from the latter, which will give the number per hour, which divided by 60 will give the number per minute. Example: Suppose your counter shows the number 1878, and at the end of the hour it shows 4878. Then—

$$\begin{array}{r} 4878 \\ 1878 \\ \hline 60)3000 = \text{Per hour.} \\ \hline 50 = \text{Per minute.} \end{array}$$

Marking Engines.

Q. What advice would you give to an engineer on taking charge of a new or strange engine?

A. He should mark with a scriber, or cold chisel, the different working parts, so he can easily replace them, should they slip. Thus, should he mark the

eccentric and shaft at the same time, and if the eccentric should afterward slip, he can easily reset it by merely bringing the chisel-mark on the eccentric in contact with the mark on the shaft. All keys should be marked, and then you can tell at a glance if they are working loose. Set-screws are a very unreliable means to secure eccentrics or other parts together, and they should never be used when they can be secured by a key.

Horse-power of an Engine.

Q. What is meant by the horse-power of an engine?

A. A horse-power is equal to lifting 33,000 pounds one foot high in one minute.

Q. How is the horse-power of an engine determined?

A. Find the number of square inches in the piston, then multiply that by the pressure of steam plus the pressure due to the vacuum,* and then multiply this sum by the number of feet the piston travels per minute, and divide by 33,000; the result is the horse-power.

Q. How do we find the number of square inches in the piston?

A. Square the diameter, and multiply by the decimal .7854.

Q. Will you give an example?

A. Suppose your engine is 40 inches in diameter, and 10 feet stroke, and makes 20 revolutions per minute. Pressure of steam per gauge, 30 pounds

* If a condensing engine.

per square inch. Vacuum 26 *inches*—not pounds. As 30 inches of vacuum is equal, in round numbers, to 15 pounds pressure, every two inches of vacuum equal one pound pressure.*

Now, we square the diameter 40
by multiplying it by 40
1600
And that by the decimal .7854
6400
8000
12800
11200
1256.6400 which is the number of square inches in the piston.

Now, leaving out the fraction .6400, we take the whole number 1256 (which is near enough for practical purposes) and multiply it by the pressure, which is:

Steam 30
Vacuum 13
43 = total pressure.
1256 = square inches.
43 = pressure.
3768
5024
54008
And that by 400 = speed of piston in feet per minute.

33.000)21603200(654$\frac{200}{330}$ Horse-power.
198000
180320
165000
153200 — 20 revolutions.
132000 — 20 feet per revolution.
21200 — 400 feet per minute.

* In non-condensing engines, there being no vacuum, the pressure due to it is omitted. In such a case the steam pressure (30) would alone be used in the above example.

which gives 654 and a fraction horse-power. In this example the steam follows full stroke, and the engine exerts its greatest power. When the steam is cut off the *mean* pressure must be taken; but it is always best to calculate with full stroke, and thereby find the greatest power the engine is capable of exerting.

To find the Mean Pressure.

Q. Can I find the mean pressure by means of hyperbolic logarithms?

A. Yes; divide the length of the stroke by the length of the space into which the steam is admitted; find in the table the logarithm of the number nearest to the quotient, to which add 1, the sum is the ratio of the gain; then find the terminal pressure by dividing the initial pressure by the proportion of the stroke during which the steam is admitted, and multiply it by the logarithm + 1, found as above; the product will be the mean pressure through the stroke.

Example 1.—Suppose the length of the stroke to be 48 inches, the initial pressure to be 40 pounds per square inch, and the steam to be cut off at 12 inches of the stroke, what will be the mean pressure?

$48 \div 12 = 4$. Hyp. log. of $4 = 1.38629 + 1 = 2.38629$.

Then, $40 \div 4 = 10 \times 2.38629 = 23.8629$ pounds, the mean pressure required.

Example 2.—Suppose the length of the stroke to be 36″, initial pressure to be 50 pounds per square inch, and the steam to be cut off at 9″ of the stroke, what will be the average pressure?

$36 \div 9 = 4$. Hyp. log. of $4 = 1.38629 + 1 = 2.38629$. Then $50 \div 4 = 12.5 \times 2.38 = 29.75$, mean pressure required. This is correct without taking the clearance into account. With the clearance added the mean pressure would be slightly greater.

Table.

No.	Logarithm.	No.	Logarithm.	No.	Logarithm.
1.25	.22314	5.	1.60943	9.5	2.25129
1.5	.40546	5.25	1.65822	10.	2.30258
1.75	.55961	5.5	1.70474	11.	2.39789
2.	.69314	5.75	1.74919	12.	2.48490
2.25	.81093	6.	1.79175	13.	2.56494
2.5	.91629	6.25	1.83258	14.	2.63905
2.75	1.01160	6.5	1.87180	15.	2.70805
3.	1.09861	6.75	1.90954	16.	2.77258
3.25	1.17865	7.	1.94591	17.	2.83321
3.5	1.25276	7.25	1.98100	18.	2.89037
3.75	1.32175	7.5	2.01490	19.	2.94443
4.	1.38629	7.75	2.04769	20.	2.99573
4.25	1.44691	8.	2.07944	21.	3.04452
4.5	1.50507	8.5	2.14006	22.	3.09104
4.75	1.55814	9.	2.19722		

Thumping of Engines.

Q. What causes engines to thump, especially when the engine is passing the centers?

A. The causes are many and various. It may thump because the shaft, cross-head, or slides are out of line; the crank-pin, shaft or couplings may be loose; there may be and often is a collar formed in the cylinder by long wear, against which the piston brings up as it passes the centers, in which case the collar must be chipped or filed off. Some of the keys of the stub or

fork-end of the connecting-rod may be loose; the piston packing may be loose, and need setting out; or the valve and its gear may be out of order. On hearing a heavy and unusual thump or noise about your engine, first examine all the keys and caps, to see if they are tight; if they are all right, take off the cylinder-head and see if a collar has formed in the cylinder; if not, examine the piston packing, and set it out if necessary. Try the piston itself; it may be working loose on the rod. If the air-pump is worked by the main engine, examine its piston; perhaps it will be found loose; next examine the main valve, and see if it has the usual lead; also, the eccentric and link motion. Having done this, and all having been found in order, if the thumping still continues, you may take it for granted that the shaft, slides, or cross-head is out of line, and you must line it up as directed below.

Lining up an Engine.

Q. How would you proceed to line up an engine?

A. Sometimes when the engine thumps, or otherwise works badly, it is advisable to try its different parts to see if they are in line. To do this, assuming that the cylinder is in its proper place, we run a line through the center of the cylinder, measuring from different points to get the line exactly in the center, and make it fast in the crank-pit; then—

To Line up the Slides.

Measure with a straight-edge the distance of the

slides from the line at the top and the bottom, and if the measurements are not the same, liners must be used to set them true.

To Line up the Cross-Head.

If the connecting rod has a fork-end, and there is a hole in the cross-head for the piston-rod, if the line does not pass through the center of the hole, the cross-head is not true, and the gibs must be adjusted to make it so.

To Line up the Shaft.

To line up the shaft, bring the crank around nearly on the top center, just so that it will touch the string, measure the distance of the forward end of the crank from the line, then turn the crank around on the bottom center as before, and measure the distance of the crank again. If all the measurements are the same, the shaft is in line, that is, it stands at right angles to the center of cylinder; but if the measurements are not the same, the shaft is out of line, and it must be raised or lowered until the measurements are the same. Example: Suppose the crank-pin be 5 inches long, and (taking an extreme case) the distance of the string is 3 inches from the forward crank, and 2 inches from the after center, and the reverse when on the bottom, it shows the forward end of the shaft is down, and needs raising $\frac{1}{2}$ inch. Of course, the example is an extreme case, and in practice the measurements will seldom differ more than $\frac{1}{8}$ inch. This method saves the trouble

of taking out the crank-shaft, which would have to be done to use a T-square for the same purpose.

Q. As the above rules are for vertical or upright engines, give a rule for horizontal engines.

A. Remove the piston, and stretch a line through the cylinder, making the end fast to something beyond the crank-shaft. Set this line exactly central by the counterbore at the outer end of the cylinder, and by the bore of the stuffing box at the inner end. Set the outboard pillow block presumably right, and clamp it so that it will not move. Turn the shaft in either direction till the pin comes to the line, and measure accurately the distance from either shoulder of the pin to the line. Turn the shaft in the other direction till the pin comes to the line, and measure as before from the same shoulder to the line. If the two measures agree, the shaft is square with the bore of the cylinder. It is also necessary to set the crank-shaft in line with the cross-head pin. For this purpose drop a plumb line from the floor overhead, and so that it shall hang one-half the diameter of the crank-pin back of the center of the crank-shaft, and anywhere between the shoulders of the crank-pin (for convenience of measuring). Turn the shaft so the crank-pin is directly up, and measure from the shoulder to the line, and also turn it so the pin is down and measure the same. Raise or lower the outboard pillow block until the two measures agree. Of course this is on the supposition that the cross-head pin is square with a plumb line—in other

words, that it is level. This can be determined in various ways, according to the peculiar construction of the engine—as by an accurate level on the slides, or by a straight edge set vertically and compared with a plumb line, etc. If, however, the cross-head pin is not square with the plumb line, and it is not thought best to level up the bed, accurately measure how much it is out of square, and make an equal allowance when setting the shaft by the plumb line.

Straps, Gibs and Keys.

Q. Will you explain the strap-ends of connecting and other rods?

A. In Fig. 117 is shown the simple form of a strap-end connecting-rod. It is a very convenient form to put up and take down, but as the strap moves up the rod-end as the brasses are keyed together to take up the wear, it gets shorter, and there is no very ready method of showing how far the strap should be set back, nor where the center of the bore of the brasses should stand to maintain the rod of its original length from center to center of the bore of the brasses. The result is that the length of the rod is apt to be altered when the slips of iron are put behind the brasses to set the key up. This alters the location of the piston-stroke in the cylinder, giving less clearance (between the piston-head when at the

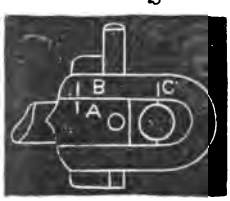

Fig. 117.

ends of its stroke and the cylinder-cover) at one end and more at the other, sometimes causing the piston-head to strike the cylinder-cover. Furthermore, there sometimes exists at the ends of the cylinder a ridge of metal, caused by the piston-head not traveling from end to end of the cylinder bore, and by the wear of the cylinder, so that the diameter of the bore is not so great at the ends. Hence when the location of the piston-stroke is altered, the piston will strike this ridge at one end and not meet it at the other end of the cylinder, wearing away the existing ridge at the first end, and increasing it at the last-named end. As a guide to avoid this, we may mark on the face of the rod-end a deep line, A, in the engraving, and a similar line, B, on the strap. Then another line, C, on the strap, and if in lining up the brasses to set the key back we make A and B come even, and the center of the bore of the brasses come fairly beneath C, the rod will be kept of its original length so far as that end is concerned. If in this kind of rod-end the joint face of the two brasses butt tightly against each other when the brass bores are a proper fit to the crank-pin, we may drive the key tightly home, and the strap will be firmly locked by the key to the rod-end, so that the key and gib will not be subject to much wear. But if the brasses are left open at the joint so as to be able to take up any lost motion (due to the wear) without filing the joint faces, the key cannot be driven home, because that would bind the brasses upon the journal; hence, in this case, the

strap is not locked to the rod-end at all, but hangs (as it were) thereon. In this latter case the wear is many times greater because of the difficulty of adjusting the brasses so delicately as not to have any lost motion (and therefore no thumping), and, at the same time, not to bear too hard against the journal.

In Fig. 118 is shown a bolted connecting-rod-end, A, B being the brasses, C a strap, and D E two bolts. This class of rod is used mainly on marine engines. Here we have no means of correcting the length, and great care must be taken to place behind the brass, A, a liner of the proper thickness, to compensate for the wear. In this case, however, there might be marked upon the rod a deep line, which should always stand at a known distance from the center of the journal, that distance being marked beside the line as at F in the figure where it is marked as 4.

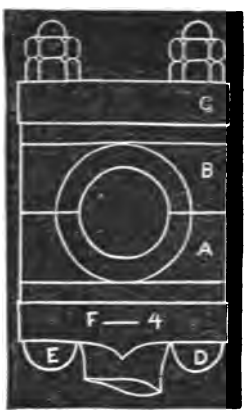

Fig. 118.

Liners.

Q. As all brasses wear more or less, what is to be done when the wear is considerable?

A. When the brasses have worn until they are "brass to brass," that is, when much worn and have been keyed up until they touch, they must be taken

and filed off until they do not touch by $\frac{1}{8}$ of an inch. The amount taken off is then made good by placing "liners" (thin pieces of copper, sheet-brass, tin or sheet-iron) between the brasses and rod-strap or cap. The English practice is to bind all brasses "brass to brass," filing them down as they wear, which is the better plan. Care must be taken in using liners, when the clearance is small, not to lengthen or shorten the connecting-rod, so as to cause it to strike the top or bottom of the cylinder. After overhauling an engine in any way, it is always advisable to turn it over *by hand*, to be sure that all is clear before getting steam.

Q. What is meant by clearance?

A. Clearance is the distance of the piston from the top or bottom of the cylinder, when the engine is on the true center. Most engines have about $\frac{3}{4}$ inch clearance, and the liners should be used so as to keep it at that. The object in using liners is to keep the rods, etc., at their proper length.

Scaling Boilers.

Q. In what manner is the scaling of boilers performed?

A. The scale is chipped off with sharp-faced hammers called scaling-hammers, and those parts which cannot be reached with the hammers, with long flat-faced bars called scaling-bars. After the scaling has been performed the boiler should be thoroughly washed out, and all the scale, mud, etc., taken out of the lower handholes.

Q. Are not certain chemical compounds used for removing scale?

A. It is said that all such compounds injure the iron while removing the scale, and therefore the better plan is to use hammers, as before directed.

Sweeping Tubes.

Q. How are the tubes swept?

A. With brushes, made for the purpose, fixed to long iron rods. Some engineers blow them clean with steam, using a piece of steam hose with a nozzle just fitting the tube. This is a quick way of doing it, and it can be done with steam in the boiler. Sweeping tubes is a most disagreeable and dirty job. Nevertheless, they must be swept at least once a week, or they will become choked up with dirt and ashes, kill the draught, and cause the boiler to steam badly.

Grinding-in of Valves, Cocks, etc.

Q. How are valves, cocks, etc., made steam and water-tight?

A. By grinding them in with ground glass, or flour emery, the glass being mostly used when grinding-in a plug-cock if it is badly cut or scratched. A great deal of labor may be saved by first draw-filing it to a fair surface, and then grinding it to a tight fit; mix your glass with oil, and apply only a little at a time. It requires both time and patience to make a good job. Plug-cocks are only used on account of their cheapness, and are every way inferior to globe valves.

Q. Is it not a difficult matter to grind in poppet valves tight?

A. It is, rather; because, though tight when cold, they will leak when hot, owing to the valve and seat not expanding alike. Every new valve leaks, after having been in use but a short time, and, as a rule, they are a constant source of trouble and expense.

Q. How are slide valves made steam-tight?

A. By scraping them to a true surface with a scraper, according to the indications of a straight-edge. The valve and face should be trued up separately, and then scraped to each other in the following manner: Take a little red lead, thinned with oil, and smear it over the valve face with your finger, wiping it nearly dry; then place the valve in its seat and slide it backwards and forwards, just as the eccentric does; wherever the lead shows in spots or patches, must be scraped. Continue this operation until the lead shows the same all over the valve and seat.

Q. What kind of a scraper should be used?

A. A worn-out half-round file, ground down (on the grindstone) to a sharp edge, will answer, if one made for the purpose is not come-at-able.

Q. Should not all brasses be scraped true to their journals?

A. Yes; and if they were there would be fewer hot journals, and less talk about an "engine wearing down to its bearings," and, if all planed surfaces were scraped, less sheet-gum would be in demand.

Packing.

Q. What kind of packing is generally used for packing stuffing-boxes?

A. There are several most excellent makes of packing, any one of which will give satisfaction. There are also several makes of metallic* packing, which are highly recommended.

Q. What is the proper way to put packing into the boxes?

A. Cut the packing in lengths equal to the circumference of the rod, less about ¼ of an inch. Fill the box, breaking the joint with every piece, and screw the gland up tight; then work the engine a little while, and when the packing has become warmed slack up the gland until the nuts are only finger-tight; the packing then will expand and become steam-tight. You must be careful in setting up the gland to see that it does not touch the rod, but sets up evenly all around.

Oils, etc.

Q. What kind of oil is the best for lubricating machinery?

A. Lard oil; and I recommend its use for the cylinder and valves, as well as for the journals. Many engineers use "cylinder oil" and tallow in their cylinders, but my experience is, that *good* lard oil is all that an engineer needs for any purpose about his engine.

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* Is the best.

Q. How often should an engine be oiled?

A. That depends upon circumstances. Some engines require oiling up every half hour, others every hour, and so on. So long as the brasses keep cool they will not cut. The proper way is to have a set time for oiling, and then go round with a squirt-can and squirt a little in each oil-hole; the crank-pin will require more than any other. The cylinder ought also to be supplied at regular intervals, and not neglected until it "grunts for grease," as it will do when it becomes dry.

Q. Is not a great deal of oil sometimes wasted?

A. There is no sense or reason in slushing an engine with oil, and a bearing, which a moderate supply will not keep cool, will be found to be keyed-up or screwed down too tight, out of line, or deficient in bearing surface.

Q. What is the proper way to key-up or screw down a journal?

A. If a key, drive it well home, and then back it out a little, say $\frac{1}{8}$ of an inch, or so, or if a screw and nut, jam the nut tight, and then turn it back a half turn or more. Of course, you must use some judgment, as I cannot give you an exact rule in all cases. Should the journal be disposed to heat, slack up more, but not so much as to cause a thump. With a little practice you will be able to do this to a nicety.

Q. Should not all the brasses be taken off and examined occasionally?

A. Yes; and care should be taken that the oil-hole does not become gummed up, or choked with dirt,

grit, etc. When cleaning-up, it is a good idea to keep all the oil-holes plugged with clean cotton-waste, to protect them from the fine ashes, etc., which are generally flying round an engine-room when repairing and cleaning-up are going on.

Q. Will not the piston-rod and valve-rods, when rough and scratched, cut the packing and cause it to leak?

A. They will; and the remedy in such cases is to draw-file the rod to a smooth surface and afterwards polish it with a piece of fine emery cloth, rubbing it in the direction of its length.

Q. What cuts and scratches the rods?

A. Dirty and gritty packing, and for this reason packing should always be kept in a clean box, or locker, free from all dirt, grease, etc.

Q. Should not all piston-rods, valve-rods, etc., be of steel, instead of wrought iron?

A. Yes, and it is generally used now for such purposes.

Q. What kind of packing is used in steam-pistons?

A. Cast-iron rings set out by steel springs; but brass rings, made of copper 15 parts, and tin 5 parts, make an excellent packing, which requires very little oil. Another advantage is, the wear is on the rings, and not on the cylinder, and it is much cheaper to buy new rings than it is to bore the cylinder out. In setting out piston-packing, care must be taken to have it neither too tight nor too loose, because if too

tight the friction will be great, requiring considerable power to move it, and probably cutting the cylinder; on the contrary, if too loose, the steam will blow through, causing a loss of steam and power.

Q. You said piston-packing is set out with steel springs?

A. Well, yes, they call them springs, but there is very little "spring" about them. Indeed, the most of them are as rigid as a screw-jack when set out. There is a fortune in store for the man who will get up a real *springy* spring for that purpose.

Q. How can one tell when the piston is tight?

A. By taking off the cylinder head and giving steam on the opposite side; when, if it is not tight, steam will blow through.

Q. What precaution should be observed in setting out piston-packing?

A. It should be set out equally all round, so that the center of the piston will stand in the center of the cylinder.

Q. How can we tell when the center of the piston is in the center of the cylinder?

A. Place one leg of a pair of dividers in the center of the piston, and the other leg where the rings touch the cylinder, and describe a circle; or use a pair of inside-calipers, measuring from some part of the spider.

Q. What is the spider?

A. It is the body of the piston itself, minus the rings and follower.

Q. Should not the rings be scraped to each other, and also to the follower?

A. They should, and the follower should be bolted down with *iron* bolts, working in brass nuts.

Q. Are not stuffing-boxes and glands made of cast-iron?

A. They are, and they should be bushed with composition, which will prevent the rods from being cut should they chafe.

Q. What tools are used in putting new packing in, or taking old packing out?

A. Almost anything made of *wood* will answer to push new packing in with, but to take old packing out, you need a packing-hook and a worm; the latter is nothing more or less than a cork-screw with a long handle. A gun-screw, such as is used to draw charges, fixed to a ramrod, is a good substitute.

Starting Fires.

Q. What is the proper way to start a fire?

A. Before proceeding to start the fire, you must see that the man and handhole plates are put on (if they have been taken off for cleaning out or repairs), and the joints properly made. If the boiler is new, or in good order, a gasket is all that is required to make them tight, but if the boiler is old and worn about the handholes, it will be necessary to put two or three turns of lamp-wick around the gasket, smearing it with white lead. After the plates are all on, fill your boiler with water until the glass gauge is half full,

then cover your grate-bars all over with coal, and put in two or three layers of cordwood (pine is the best). Then take some shavings, split wood, or oily waste, place it over and about the wood next to the door, and light it, keeping the furnace-door *open* and the ash-pan door *shut* (if there be one) until the wood is thoroughly ignited; and then, and not until then, shut the furnace-door (and open the ash-pan door if there be one) and cover the wood with coal, adding to it as fast as the wood burns away; in a short time you will have a splendid fire. Steam can be raised a half-hour sooner in this way than by the common method of putting the wood on the bare grate-bars.

Q. Must not the safety-valve be kept open while raising steam?

A. Yes, to let the air out, and be closed as steam shows itself at the escape pipe; that is, the safety-valve pipe; when the steam-gauge shows four or five pounds, open the stop-valve on the boiler, and the pet-cocks or "bleeders" in the steam-pipe and steam-chest, to free them of water; then open the throttle-valve and warm the engine up.

Before reporting "ready," if the steam is up to the required pressure, open the water-cocks on the cylinder and work the piston up and down several times, to work the water out; then turn it over slowly a few times (giving some injection water to form a vacuum*), to see that everything is all right. Fill

* If a condensing engine.

the oil-cups, also tallow-cups on cylinder, and you are ready to start. It is advisable always before starting, to look all around the engine to see that everything is clear; great damage may be done by neglecting this precaution.

Q. How thick should a fire be carried?

A. It depends altogether on the draught. If the draught is strong, it should be heavier than when it is weak, and a bituminous (soft) coal fire should be thicker than one of anthracite (hard) coal. But whatever the thickness, it should be kept spread evenly all over the grate, and not allowed to burn in holes, leaving the bars bare, as the cold air will rush in and chill the heating surface. A soft coal fire needs breaking up at short intervals, as it has a tendency to amalgamate, or crust over on top, but a hard coal fire should not be broken up with the bar. All that is necessary to clean it of ashes is to run the slice bar over the grate and withdraw it without breaking up the body of the fire. The clinkers should be taken out with the "devil's claw." Whatever is done to a fire should be done quickly, and the furnace door be kept open no longer than necessary. No two fires should be cleaned at the same time. While the cleaning is going on, the throttle-valve should be closed a little, or the steam cut off shorter, until the new fire begins to make steam again.

Q. What is the proper way to clean a fire?

A. Take a hoe and push the upper part of the fire back, leaving the clinkers, ashes, etc., on the grate,

then pull the ashes, etc., out with the hoe. To clean the back end of the grate, you pull the good fire forward again, and draw the clinkers and ashes of the back end *over* the fire, and into the ash-pan. Having cleaned it, you must spread the fire evenly all over the grate, and then cover it over with fresh coal, but not too heavily. Care must be taken with anthracite coal, not to let the fire burn too low before cleaning it, or else you will not have fire enough left to cover the grate, and it will die out.

Q. What is the proper way to bank a fire?

A. Clean it as before directed, and then push it back, leaving the front half of the grate bare, and afterwards cover it over heavily with fresh coal.

Q. Which do you consider the better. coal for steam purposes, anthracite or bituminous?

A. Some boilers are better adapted for burning hard coal than for burning soft, but which ever kind you use, get the best, clean, fresh-mined, and free from slate, etc. It is cheaper in the end to get a good article, even when you have to pay more for it. It "don't pay" to buy refuse coal and dirt at any price, and besides, the labor is hard enough with the best of coal. There is more heating power in one ton of good coal than there is in several tons of coal-dirt, and therefore it is false economy to buy the latter.

Q. How can one select a good article of coal?

A. All fresh-mined coal has a black, bright look, while coal which has been mined a long time, or been

exposed to the weather, has a kind of sun-burnt look about it, which almost anybody will notice. Coal should be kept under cover, and not exposed to the weather. I will say in conclusion on this subject, that with good coal, and a good fireman to handle it, the cost of fuel will be reduced to a minimum.

Q. What constitutes a set of fire tools?

A. A shovel, a long-handled heavy hoe for cleaning the fire, a light short-handled hoe, a devil's claw, a heavy slice-bar, and a light T-bar (a T-bar is a light slice-bar with a point shaped like the letter T) and pricker, and a coal-maul, for breaking large lumps of coal.

Foaming.

Q. What is meant by foaming?

A. Foaming, or, as it is sometimes called, priming, is a violent ebullition of the water in the boiler.

Q. What causes foaming?

A. The great cause of foaming is too little water-space and steam-room in the boiler, defective circulation of the water, owing to faulty design; or the boilers may be too small to furnish the required steam, the engine using it faster than it is formed, thereby taking off the pressure and causing the water to rise to an abnormal height; muddy water will cause it. But a boiler large enough to do the work required, of good design, with plenty of water and steam-space and good circulation, will seldom if ever foam.

Q. How can the engineer tell when the boiler is foaming?

A. By the violent agitation of the water in the glass gauge, and by the cracking noise heard in the cylinder. If he try his gauge-cocks while foaming is going on, they will blow forth a mixture of steam and water, instead of *solid* water.

Q. Is there not danger from the boiler foaming?

A. There is great danger; the water being incompressible it may be carried over in the steam in such quantities as to fill the clearance space in the cylinder, and cause the cylinder-head or bottom to be knocked out, and it destroys the vacuum. And again, when the boiler is foaming, and the glass gauge is apparently full of water, if you stop the engine the water will fall to its true level, and may drop out of the glass gauge altogether. Here we have another fruitful cause of boiler explosions. When the boiler foams, the level of the water can be found by shutting off the steam, or stopping the engine.

Q. When the boiler foams what should the engineer do to check it?

A. The first thing to do is to partially close the throttle valve, and slow the engine down, and if there be a cracking noise heard in the cylinder (which is caused by the steam carrying the water in with it), open the water cocks on the cylinder until the noise ceases. Look at the glass gauge and see how the water stands, and if the foaming be caused by too much water, blow some out. Sometimes when there

is a heavy fire in the furnace, foaming may be checked by opening the furnace door, or closing the damper, if there be one. Not only is there danger when the boiler foams, but the steam and water carry over sand, grit, and other impurities into the cylinder, which cut the cylinder face, and piston-rings, valves and valve faces, and play havoc with the air-pump and condenser.

Boilers which foam badly, or are addicted to foaming, are unfit for use, and the law should strictly prohibit the use of such dangerous rattletraps.

We give some general rules for the care and management of steam-engines and boilers, briefly stated, for ready reference.

Safety Valves.

Raise the safety valve slowly and cautiously at least once every day, as it is liable to stick fast in its seat and be worse than useless for the purpose intended. If at any time the steam gauge should show an excess of pressure, and the safety valve does not blow off, one or the other is out of order, in which case give the gauge the benefit of the doubt, and move the ball of the valve in until it blows moderately.

Glass Gauge and Gauge-Cocks.

Do not trust to the glass gauge alone, as it sometimes gets choked with the muddy sediment in the water. It should be blown through at least once an

hour to keep it clean and clear. Keep the gauge-cocks clear and in constant use, or they, too, will become choked with sediment.

Clean Boiler.

Keep the boiler clean, both externally and internally. Be *sure* and keep the crown-sheet, tubes, and all the other heating surface on the water side free of scale, baked mud, and other deposit; and the fire side free of soot, ashes, etc. When using wood or soft coal, sweep the tubes or blow them clean with a steam hose frequently. It will pay to do it, as you will not have to fire so hard. Soot and ashes are bad conductors of heat on the fire side, just as scale, baked mud, etc., are on the water side.

Blow-Cocks and Blowing Out.

Every boiler has, or should have, two blow-cocks, with pipes attached to it, one near the surface of the water, called the "surface-blow," and one near the bottom, called the "bottom-blow." As all sediment, etc., naturally rises to the surface of the water while the boiler is steaming, if using muddy or dirty water, two or three inches ought to be blown out by the surface-blow at least twice a day—in the morning and also at noon, just before starting the engine. This prevents the sediment from going over with the steam to the engine, and cutting the cylinder, piston, and valves. Use the bottom-blow only when all the water is to be blown out for cleaning out or re-

pairs. Never blow a boiler out under a heavy pressure of steam, nor until it has cooled off somewhat after hauling the fires, otherwise the rapid and unequal contraction of the metal may cause the seams or tubes to leak, and, besides, there will be enough heat left in the metal to bake the mud, etc., into a hard scale. The best plan is not to blow the water out at all, but to let the boiler cool off after hauling the fires, for several hours, raising the safety-valve to free it of steam, and then knock in a handhole plate and let it run out, provided, of course, it will not all run out by the bottom-blow without any pressure at all. The mud will then remain in a slushy condition and can easily be washed off and out with a hose, the man and handhole plates all being taken off to give the whole interior of the boiler a thorough washing out. The idea entertained by some engine attendants, that scale deposits can be blown out of a boiler by a heavy pressure of steam is entirely fallacious, as all experienced men know.

Boilers should be blown out and cleaned every week if the water be bad.

Filling up the Boiler.

Never fill a boiler with cold water while it is hot, but wait until it has cooled off, or otherwise the sudden contraction of the metal may start it to leaking in the seams, tubes, or about the patches if it be an old one which has been patched.

Prevention of Scale.

Many of the compounds used for the prevention of scale are injurious to the iron. A little coal oil (refined), molasses, carbonate of soda, tannate of soda, a few white potatoes, horse-dung, and other simple remedies answer very well, and do not injure the iron as some of the patented compounds do.

Steam Gauges.

Should the pointer or index of the gauge not go back to zero (0) when there is no steam in the boiler, it is out of order and needs looking after. Never blow the water out of the siphon bend of the steam gauge pipe; the bend is put in the pipe expressly to hold a little water to protect the gauge from the steam.

Should the pointer stick at any time jar it down by slapping the gauge sharply with the hand on the side, not on its face.

Modes of Firing.

Q. Will you explain the different modes of firing steam boilers, and which is the best way?

A. Yes, and to impress it upon your memory indelibly, I will designate each mode by a different name upon which there is no trade-mark.

The "Wedge" Method.

This is the favorite way with ignorant, careless, and lazy firemen. It consists in banking up the coal thick near the furnace door, and sloping it off to

almost a point at the back end (wedge shaped, you know). The careless or lazy fireman fires in this way because it does not require much labor to shovel coal just inside the furnace door; and the ignorant one does so because appearances deceive him. He peeps through the holes in the door and sees the whole furnace (apparently) full of fierce, roaring flames (not knowing that it is only the cold air rushing through the bars so thinly covered) and wonders why *such* a fire don't make plenty of steam.

The next method is

The "Turtle Back,"

in which the coal is carried thick and heavy in the middle of the grate, while the ends and sides are almost bare, allowing cold air to rush in all around the edges while the thick and heavy center is dead, being too thick for any air to pass through. Next we have

The "Hill and Hollow" Method,

in which the coal is kept in hills and hollows all over the bars, too thick in some places and too thin in others.

Next comes

"The Kill 'em Quick."

This consists in shovelling in coal as fast as the fire shows bright and red in any one place: the fire is thus kept smothered with fresh coal. Any man who fires according to these four barbarous methods is either careless, lazy or ignorant, and not fit to be a

fireman. They are generally the cheap Johns at the business, but great favorites with employers, as they work for small pay; but like all cheap things they cost dearly in the end.

The fifth (5th) method is known as

"The Scoop."

This consists in keeping the fire scoop-shaped, *i. e.*, thick around the sides and back and scooped out (but not too thin) in the center. This is a good way.

The sixth (6th) is

"The Pancake."

Flat as a pancake but not so thin all over the grate; in other words a fire evenly and uniformly spread all over the grate, not too thick nor too thin. This makes a clean, bright, *hot* fire, and if it don't make steam no other way will. It is emphatically the *best* way for all kinds of boilers and for all kinds of coal. The scoop is the next best.

NOTE—The thickness of a fire depends altogether upon the draft. It must be kept thick when the draft is strong, thin when it was weak, but always thick enough to keep cold air from rushing through it.

Feeding Boilers.

There are but two ways to feed a boiler with water, and they are the right way and the wrong way. The right way is to so regulate the feed by pump or injector as to keep the feed on all the time, and

thereby maintain a constant water level at the proper point. The wrong way is to feed irregularly: to keep putting on the feed and taking it off; at one time to have the glass gauge nearly empty, and then nearly full.

Glass Gauges and Blow Cocks Again.

After the work is over for the day, be sure and close the cocks on the glass gauge; and also be sure the blow cocks are closed tight, or you may come back next morning and find all or nearly all of the water gone, due to a broken glass gauge or leaky blow cocks.

Safety Valves Again.

If there should be no "pop" safety valve attached to the boiler, and a heavy banked fire be kept during the night, heavy enough to make steam, run the ball on the safety valve lever in towards the valve so that it will blow off under a light pressure. All *land* boilers should be provided with "pop" safety valves in addition to the ball and lever kind. The "Scovell" and "Crosby" "pop" valves are remarkably fine and reliable ones.

Steam Pressure.

To obtain the best result, the steam pressure should be kept uniform, not varying more than two or three pounds, instead of from ten to twenty as is the usual practice with careless, lazy or ignorant firemen. Regulate with the damper and not with the furnace door or doors.

Furnace Door Open.

If from any cause except when coaling over or cleaning the fire it be necessary to open the furnace door, immediately close the damper, to keep the cold air from rushing into the furnace and through the tubes, or leaky seams and tubes may result from sudden contraction of the metal.

Ash-Pans.

Keep the ash-pans clear of ashes, and do not permit them to accumulate until they touch the bars, causing the bars to become unduly heated and destroying the draft.

Opening and Closing of Valves, Cocks, etc.

Never open or close any steam valve, be it a safety valve, stop valve, throttle valve, nor any blow cock or gauge cock *suddenly*, but gradually. Not only steam pipes but steam boilers have been "bursted" by neglect of this precaution.

Grate-Bars.

When putting in grate-bars do not place them too close together, but give them both end and side play, as they expand considerably when hot, and if they have not room to expand they will bend or twist out of shape and soon be destroyed.

Glass Gauge Bursts.

Should the glass gauge burst, shut off the *water* first and afterwards the steam.

Looking into the Furnace.

Do not open the furnace door every five minutes and keep it open while you take a long look at the fire. Once every half hour is often enough if you understand your business as a fireman.

The First Thing to do,

Before spreading your fire in the morning, is to see if there be enough water in the boiler to start the fire on. Many a man has left plenty of water in his boiler at night and come back next morning and found it all or nearly all gone, caused by the boiler springing a leak, the glass gauge bursting, or the blow cock leaking during the night. Whatever you neglect to do, do not neglect this precaution.

The Last Thing to do,

Before going home at night, is to look around the fire room and see if there be any hot coals lying around loose, or matches, greasy waste, or anything which may cause the building to take fire during the night.

Hot Crank-Pin.

Should the crank-pin get hot, stop the engine at once; then slacken up the key and cool it off with hot water from the boiler, and finish off with cold water. Afterwards key up moderately tight, and oil well before starting again.

Loose Belts.

When the belt slips it will cause the engine to race, which is dangerous to both the engine and the engineer. All the engineer can do at the moment is to throw two or three handfuls of pulverized rosin on the pulley just where the belt grips it; but this only gives temporary relief. The Norris pulley cover is a sure and permanent cure for slipping belts. It can be used either with leather or rubber belting. Fig. 119 shows this cover applied to a pulley. Mr. C. L. Wright, 104 Duane street, New York, is the manufacturer.

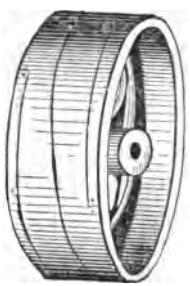

Fig. 119.

Governor Belts.

These require special attention, for unless the governor be provided with a safety stop, and the belt break, before the steam can be shut off, the engine may wreck itself.

Stuffing-Box Glands.

After packing a stuffing-box, be careful and set the gland up square all around the rod. Not only have piston rods been badly cut, but the packing has been set on fire in the box by the rod rubbing against the gland.

Loose Boxes.

By placing the hand on the connecting rod while the engine is in motion, you can tell if there be lost motion in the cross-head or crank and brasses by the jar felt in the rod.

Patent Automatic Oil Feeders.

These improvements need constant watching, as they sometimes fail to feed at all, and the engineer is sometimes reminded of that fact by the smell of hot grease when he least expects it.

Gum Joints.

In making gum (rubber) joints on the flanges of steam pipes, too little attention is usually paid to bringing the flanges fairly together. The reason for this is that it is generally possible to make such joints for the time being with the flanges considerably out of truth. This is all wrong, however, as the packing is unevenly compressed, and the strain on the pipe, incident to screwing up the joint bolts constantly, tends to loosen the packing. Joints made in this way last but a short time, and the iniquity of the individual who does the job is charged against gum packing generally.

Flanges for gum joints, while they should be turned quite true, should not be too smooth. They are much better as left by the pointed tool and reasonably coarse feed, than when finished with a smoothing tool. The flanges should come together quite fair, and the bolts, plenty in number, be screwed up evenly. After being warmed up the bolts should be tightened, which operation should be repeated once a day for three or four days.

Gum joints treated in this way, which is only reasonable, have a habit of lasting, which goes far

towards redeeming them from the disgrace into which they have quite generally fallen.

Asbestos mill board is much superior to sheet gum for making steam joints tight, as the heat has no effect on it, and it will stand the highest pressures.

No matter what happens, keep cool: don't get excited: a cool head and a steady hand are what an engineer needs above all else when emergencies arise. Remember break-downs and accidents will happen with the best and most experienced men. Tell your employer so—if need be—but be sure it does not happen through carelessness or ignorance on your part.

From what has been written the reader should be able to take charge of and run an engine intelligently. Still books are but *aids*, and constant study and observation, together with his own experience—experience, the greatest and best of all teachers—will enable him to rise in his truly noble calling.

Horse-Power of Boilers.

Q. Will you give me a rule for finding the horse-power of boilers, or in other words I wish to find the heating and grate surface required for each H. P. in different types of steam boilers?

A. There is no recognized standard rule for the H. P. of boilers, either in this country or in England, but there are general rules which are used for boilers intended for economical work, viz.: for plain cylinder boilers allow 15 feet of heating surface, and 1 square

foot of grate surface; for flue boilers 15 feet of heating surface and $\frac{3}{4}$ square foot of grate surface, and for tubular boilers, well proportioned, 15 to 16 square feet of heating surface and $\frac{1}{2}$ of a square foot of grate surface for each H. P.; a little more grate surface will give better results in some cases. The above are the proportions for boilers and grate surface, but in regard to the amount of heating surface allowed per H. P. we would say from 12 to $12\frac{1}{2}$ feet as a safe rule to follow. It is not a good plan to go to extremes in allowing an excess of heating surface, for in it there is no economy, as is erroneously represented by some manufacturers. A 15 H. P. boiler is too large for a 10 H. P. engine; in other words, it will not work with the same economy as a properly proportioned boiler.

Shafting Out of Line.

Q. What is the remedy for shafting out of line?

A. Shafting is always liable to get out of line; therefore, it is well to line up as often as twice a year, to be sure that all is right. It has been in times past a common thing to allow shafting to run as long as it would go without adjusting, and then stop the works for a day or two to line up, which is unnecessary, and only a loss of time. A shaft may be leveled by almost any one when the hangers are properly made, and can be done at noon, or after stopping in the evening, without interfering with the business at all. But enough time should be allowed to insure a good

job. To line a shaft horizontally is but little more trouble, if the bearings or hangers can be moved in that direction. Suspended hangers should have the bolt-holes slotted for an inch or more of movement, and post-hangers should have movable bearings and permit side adjustment. Assuming that there are some means of moving the shaft horizontally, a good plan of adjusting it is by suspending a number of plumb-lines that will bear against one side of the shaft, and reach down low enough to be sighted from the floor.

When a shaft is continuous over several bearings, and presuming that the bending load is evenly distributed, the bending strains, and consequently the resulting longitudinal strains, are greatest at the bearings, being at this point double what they are at a point midway between bearings, and the bending strains are least at the points of contrary flexure, which points, in this case, will be at a distance from either bearing slightly over one-fifth of the distance between bearings. Thus, if a continuous shaft has its bearings ten feet apart, the couplings ought to be two feet from the bearing.

As pertinent to this subject, the writer offers the following arithmetical formulas for the diameters and the distances between bearings of line shafting of wrought iron, premising that every special case requires its own proper determination, the rules being empirical, but believed to be sustained by correct practice, in average shop and mill work.

For shafting carrying ordinary belting and pulleys

$$\frac{80 \text{ H. P.}}{\text{R}} = \text{cube of diameter of shaft in inches.}$$

$$\sqrt{\text{diam. of shaft in inches}} \times 6\tfrac{1}{2} = \text{greatest distance between bearings in feet.}$$

When the shafting merely transmits power carrying no pulleys,

$$\frac{60 \text{ H. P.}}{\text{R}} = \text{cube of diameter in inches.}$$

$$\sqrt{\text{diam. of shaft in inches}} \times 10 = \text{greatest distance between bearings in feet.}$$

H. P. = horse power transmitted.

R. = revolutions of shaft per minute.

These rules do not apply to the head shaft, where the power is first received.

Grinding Poppet Valves.

Q. Give me a rule for grinding poppet valves?

A. The engineer of one of our large river boats, who always seems fortunate in having tight valves, attributes the secret of their keeping in that condition to the fact that he grinds them but little, and never with any harsh grinding material. His plan is to grind with fine quartz till they show a seat; then wipe the valve and seat quite clean, oil with sperm or lard oil, and continue as if grinding for some hours, and until the two surfaces have a fine mirror-like appearance.

It is probable that the rubbing process hardens

both valve and seat, leaving them in the best possible condition to resist the cutting action of steam across their surfaces. It is well known that valves ground with harsh, rapid-cutting material, though they may be tight at first, soon commence to leak, from the fact that the surfaces are soft and spongy as well as uneven in density. If left in this condition, the steam gets a slight start through the softer places, and soon cuts channels that destroy valve and seat.

Cleaning Water-Line Glasses.

Q. Will you inform me of the best method of cleaning water-line glasses?

A. Remove the glass and clean with a solution of potash, using a swab on a *handle of wood.* Never use a rod of metal, as the glass is liable to break wherever it comes in contact with it, even lightly.

Spring for Indicator.

Q. In selecting a spring for an indicator how can I select a spring for a given pressure?

RULE.—Divide the boiler pressure by 2.5; the quotient is the proper number of spring.

EXAMPLE.—Boiler pressure, 75 lbs.$\div 2.5 = 30$.

It is good practice to use as low a number as will do for the pressure, so as to get the diagram on a large scale.

To Find the Sizes of Cylinders.

Q. Give me a rule for finding the sizes of cylinders and point of cut-off for a compound engine, when

the initial and terminal pressures, horse power and piston speed are given.

A. Take the example given, viz.: horse power, 100; initial pressure, 60 pounds (gauge); and piston speed 400 feet. First find the number of times the steam is expanded. Rule: Divide the absolute initial pressure by the terminal pressure. The quotient will be the number of times the steam is expanded. Thus, $\frac{60+15}{15} = 5$, which is the number of expansions in both cylinders. The area of low pressure cylinder is the same as the area of the cylinder of a simple cylinder engine working under the same expansion; hence find the mean pressure as for a simple cylinder by the following rule: Find the hyperbolic logarithm for the number representing the expansion, to which add 1, and multiply the sum by the terminal pressure. The product will be the mean pressure. The hyp. log. of 5 is 1.609, and $1.609+1=2.609$, and $2.609 \times 15 = 39+$, which is the mean pressure in pounds per square inch. The area of cylinder is found by the following rule: Multiply 33,000 by the number of horse power, and divide the product by the piston speed, multiplied by the mean pressure. The quotient will be the area of the cylinder in inches. Thus, $\frac{33{,}000 \times 100}{400 \times 39} = 211.5+$, which corresponds to a diameter of about $16\frac{1}{2}''$. The diameter of high pressure cylinder should be such as to equalize the

maximum strains on the two pistons; in other words, the expansion should be the same in each cylinder. Hence to find the area of high pressure cylinder: Divide the area of low pressure cylinder by the square root of the number of times the steam is expanded. The quotient will be the area of high pressure cylinder in inches. Thus, $\frac{211\frac{1}{2}}{\sqrt{5}} = 94.5.+$, which corresponds to a diameter of about 11″. To find the point of cut-off in high pressure cylinder: Divide the area of the high pressure cylinder by the area of the low pressure cylinder. The quotient will be the fraction of stroke which should be made before steam is cut off. Thus, $\frac{94.5}{211.5} = .446+$ which is the point of cut-off in the high pressure cylinder measuring from the commencement of the stroke. For the problem submitted we have: Diameter of low pressure cylinder, $16\frac{1}{2}$″; diameter of high pressure cylinder, $11\frac{1}{2}$″. Point of cut-off in high pressure cylinder, .446 of stroke. This consideration of the subject is purely theoretical, and expresses what ought to be rather than what is. For instance, an allowance must be made for back pressure, loss of pressure between the cylinders, friction of engine, etc. No absolute rule can be given for this, nor even an approximation, unless all the details of construction are known. In practice the dimensions of cylinders, as found above, would be increased to an extent which corresponded to the individual builder's taste or experience.

Hot Journals.

Q. Is it a good plan for the treatment of a hot journal, which runs in a box lined with Babbitt metal, to apply cold water until the bearing is cold?

A. Yes. As soon as the heat is reduced apply tallow containing a large percentage of graphite (black lead), which will restore the surface of the journal if not too badly cut. Sulphur is good to cool a journal but it is to be dreaded afterwards, as it forms scales which will again cut the journal; it may take a little longer to cool the journal with the former compound, but it is the best in the end. 2. Is water a good lubricator? *A.* No. This was proved conclusively by the experiments of General Morin. 3. Why do sulphur and plumbago tend to cool hot journals? *A.* There is nothing in either one which possesses the qualities of cooling hot journals. The philosophy of the phenomena is this: The plumbago or sulphur being put on a journal, the fine powder fills up the cavities and grooves caused by the heating and abrasion of the surfaces, thus forming, as it were, a new surface. Plumbago being of a fine metallic nature puts a polished surface upon a journal which with a little attention will cool down and cause no more trouble.

Condensing Surface.

Q. We have a compound engine, high pressure cylinder, 14″x16″; low pressure cylinder, 26″x16″; boiler heating surface ample. We calculate to run

the engine 150 revolutions per minute, using steam at ninety pounds pressure. We are provided with an air pump, 6″ diameter by 12″ stroke, and a circulating pump of a capacity of 8,000 gallons per hour. We wish to know the least number of square feet of condensing surface we can depend on for a satisfactory vacuum. We propose to make our surface condenser of brass tubes, $\frac{5}{8}$″ outside diameter, and to use the steam inside and water outside the tubes. Would a different style of air and circulating pump make any difference? What would be the difference with the steam on outside of tubes?

A. The condensing surface should be proportioned to the amount of steam used, which would in turn depend on the point of cut-off. It is also proportioned to temperature and quantity of water circulated. We should, as we understand the conditions, make a condenser having 600 feet of cooling surface. Condensers are made with the water inside or outside of tubes, according to the views of the builder. When properly constructed and proportioned, they work satisfactorily either way. You do not describe your air pump, but there should be no difficulty with that. The particular kind of circulating pump is immaterial, so long as the water is supplied as wanted.

Speed of Engine and Velocity of Piston.

Q. Does an increase of speed of an engine increase its power as indicated by the dynamometer? Of course it would if the shafting it was driving was

geared down to its former speed, but that is not the question, steam pressure is constant.

A. The power of an engine increases as a direct ratio of the velocity of the piston. For illustration, take an engine with a cylinder 20 inches diameter, and 24 inches stroke, running at a velocity of 50 revolutions per minute, with a mean effective cylinder pressure of 30 pounds. Then the area of piston multiplied by 200, the velocity of piston in feet per minute, and that product divided by 33,000, the equivalent of one horse-power, and the quotient multiplied by 30, number of pounds mean effective pressure will give a result of 27.810 H. P. Now take the same engine, all other things being equal, with a velocity of piston of 400 feet per minute, and the result will be 55.620 H. P., and as a third example, take a piston velocity of 600 feet per minute and the result will be by the above rule, 83.430 H. P. Gearing the shaft down would make no difference as the indicator is to be placed on the engine to ascertain the actual developed H. P.

Diameter of Flues and Tubes.

Q. Give me a rule for proportioning the diameter of flues and tubes to suit the diameter of shell of boiler?

A. The *total* tube area of boilers must not be less than one-eighth ($\frac{1}{8}$), and not *more* than one-fifth (1-5th) the total grate surface of boiler; grate surface with natural draught from 32 to 34 to 1 compared with

heating surface. Experiments made by W. H. Hoffman, with fifteen (15) different boilers, showed that the total tube area gave the best evaporation when sub-divided fifty-four (54) times, the tubes being forty-eight (48) diameters long, and the shells all being above 42″ in diameter, the largest being 66″ diameter. Now, as tubes less than 2½″ in diameter are entirely useless with natural draught, shells under 42″ should not and really cannot, with any economy, be sub-divided more than thirty-six (36) times; and thirty (30) divisions on a 36″ shell will give within a fraction the same evaporation as a 3½″ tube in a 66″ shell, provided the 2½″ is no more than forty-eight (48) diameters long. There are no text-books that give the proportions asked for.

Pressure to be Allowed a Boiler.

Q. Please give me a formula for calculating the pressure to allow a boiler, the diameter and thickness of boiler plate being given.

A. Formula: $P = T \times C \div D$ in which P=Bursting pressure, D=Diameter of shell, C=Constant, being 1097 for single riveted iron, and 1372 for double riveted; 1723 for single riveted steel, and 2156 for double riveted. The stays upon the heads should be 5½″ from center to center. If these directions are followed, the boiler will be likely to give satisfaction.

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